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SCHOOL SCIENCE AND MATHEMATICS

VOL. XXXII NO. 5 MAY, 1932 WHOLE NO. 277

BIOLOGY TEACHING AND VISUAL AIDS*

BY WINIFRED PERRY,

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Biology has an important contribution to make to the education of a twentieth century youth in a twentieth century world. The inculcation of correct attitudes of civic consciousness as regards matters of personal and community health, conservation problems, a more tolerant attitude toward other nations and a more worthy use of leisure time are desirable outcomes of all biology teaching. What we shall teach is fairly well agreed upon. How we shall teach it is a problem worthy of considerable discussion.

Teachers of biology have employed visual aids since the day the botany or zoology instructor brought a specimen into the classroom to illustrate the lecture of the day. Perhaps biology teachers more than those of any other subject have been dependent upon visual aids to clarify their teaching. But as with the content of biology courses which stressed first one phase and then another of the subject, the question of visual aids has been largely a matter of emphasis. For many years teachers have used charts, slides and museum specimens as a matter of course. Today we use them with a new consciousness of their value in teaching; we give them an emphasis which was formerly accorded only to demonstrations and experiments.

For some time there has been a trend toward the

*Read before the Department of Science Instruction N. E. A. at Los Angeles, Calif., June 29, 1931.

placing of more emphasis upon natural history in all elementary biology courses. Requirements for a teaching license in biology, now necessary in the state of New York, includes a field test for the identification of common plants and animals. Teachers are realizing that they are not training their pupils for college science courses but for living. They should be given lasting appreciations of the beautiful and interesting in their environment.

"There should be a Back to Nature Movement among biologists. By cutting out fads and fancies, a single biology course should be given which should contain more old fashioned natural history or ecology, more knowledge of plants and animals and less of their detailed insides, enriching the student's life by a closer association with the life about him."[1]

In teaching such courses as have just been described or a course in which the principles of biology[2] are given first consideration, the actual specimens or realia, a term coined by Miss Annette Glick of the Visual Education Department of the Los Angeles City Schools, deserve first consideration. A field trip to see the plant or animal in its actual environment would be the most desirable procedure. Wm. G. Vinal believes that money spent for textbooks might well be spent for field trips, and says that "Students have as much right to read the fields as about the fields."[3]

However every teacher in a town or city high school knows the difficulties that must be overcome before an excursion is undertaken, and so specimens are of paramount value and importance.

A living specimen is far superior to a dried or pickled one. A living starfish will arouse interest as a dried one will never do. But every teacher knows the difficulty in finding the material for class use when she needs it, and an adequate supply of museum specimens is essential in every school.

Now that the demonstration performed by the teacher

[1]Varrelma, F. A., "On Teaching Living Biology," SCHOOL SCIENCE AND MATHEMATICS, March, 1931, pp. 273,274.
[2]Bayles, E. E., "The Organization of the High School Biology Course," Science Education, January, 1931, pp. 75-82.
[3]Vinal, Wm. G., "Humanizing Biology," SCHOOL SCIENCE AND MATHEMATICS, February, 1931, pp. 228-231.

has replaced the individual pupil experiment in so many schools,[4],[5], the preparation of such specimens provides an excellent form of pupil activity. Insect specimens, shells and seaweeds, as well as valuable plant specimens may be safely and attractively preserved in some form of a Ricker mount. Pupils should be encouraged to make these containers as well as to collect and prepare the specimens. Bird skins and the skins of small mammals may be exhibited in tubes made of rolls of celluloid with end pieces of wooden dowling. A neatly typed or written label should be pasted on the back of each small exhibit case. This label should give the scientific and common names of the specimen, the locality and date when found and the name of the donor. While these realia should be largely of the local environment, specimens from other localities which may be obtained through an exchange of material by schools or biology clubs are of great interest and value to pupils. These specimens should be given a prominent place in the school museum, which should also contain commercial exhibits that are of interest to biology pupils. Sources of supply of these so-called commercial exhibits may be found in the publication from Teachers' College, Columbia University, "Enriched Teaching of Science in the High School."[6]

Charts are an accepted part of the equipment for all biology teaching. Certain types of printed charts are almost indispensable. In the field of human biology the W. and A. K. Johnston Company's physiology charts are too well known to require any comment here. The new Winslow Health Charts published by the Denoyer Geppert Company cover the field of physiology and public health in a most admirable way. The American Medical Association sells for a nominal sum a set of charts which deal with patent medicines and the fundamentals of dietetics. There is a great variety of charts in the fields of botany and zoology with special material for bird and insect study. Some charts from the United

[4]Downing, Elliot R., "An Investigation to Determine the Time Required to Teach Certain Units in Biology," Reprint from North Central Association Quarterly, March 31, 1931, 18 pages.

[5]Herrick, Louise, "A Unit in Ninth Grade Biology," SCHOOL SCIENCE AND MATHEMATICS, January, 1931, pp. 70-74.

[6]Woodring-Oakes-Brown, "Enriched Teaching of Science in The High School," Bureau of Publications, Teachers' College, Columbia University, New York City, 1928.

States Department of Agriculture and The United States Public Health Service are worthwhile additions to this form of visual aids in biology.

Chart making furnishes an excellent form of pupil activity. Life histories of insects, frogs and toads, ferns and higher plants may be put into chart form. The graphic chart showing the decrease of certain communicable diseases, the amounts of alcohol in patent medicines, the amounts of protein, calcium and iron in common foods may be shown in this way.

The picture chart made by cutting pictures from advertisements in magazines has great possibilities. In the teaching of hygiene these charts are especially effective, and they are likewise adapted to various botanical studies, as for example, the various types of fruits—berry, pome, drupe, akene and so forth.

Flat pictures used on bulletin boards may be utilized to illustrate any subject in biology. Pupils never tire of viewing and contributing to these illustrated lessons. Teachers who file flat pictures under large divisions corresponding to the commonly used units in biology never lack this form of illustrative material. Magazines have been especially rich in this material during the last few years.

The twenty thousand biology teachers who receive Turtox news each month are aware of the constantly increasing numbers of biological models which are offered by the General Biological Supply, Chicago. Then there are equally excellent models sold by Denoyer-Geppert Company, Chicago, and by other concerns as well. In problems involving cell structures, for example, nothing is more useful than a well executed model to help the young pupil visualize mitosis, root or leaf structure, or the anatomy of cray-fish, earthworm or of man himself. These models are quite expensive, but if a few well selected ones are added each year, a department will have a good collection in a few years' time.

The projected picture is usually the layman's idea of visual education, and the biology teacher finds the several types of projected pictures an indispensable aid to good teaching. It would seem that every school would

be equipped to use some type of projected pictures, but the chief of the bureau of Visual Instruction, Extension Division, University of Wisconsin paints a different picture. "It ought not to be necessary to argue the value of pictures as aids in learning today, but judging by the large percentage of our teachers—yes, the many, many schools—who have never employed stereographs, lantern slides or educational motion pictures in their classrooms, there must be many teachers and school administrators who do not believe that pictures in their various forms do vitalize classroom teaching."[7]

The slide, opaque picture, film strip, still film and moving picture, either silent or with sound, are aids to good teaching but should not be considered a method in themselves. "Unless pupils are led to pay attention to particular points of importance, they may grasp little more than they would have done from a printed page."[8]

The preview by the teacher is an absolute necessity and without it the lessons often result in a waste of time and become a mental narcotic instead of a mental stimulant.

The baloptican is a widely used piece of apparatus permitting the projection of opaque pictures and glass slides. Pupils should be encouraged to work up sets of opaque pictures that will serve as a summary or review of the various units of work, or that will illustrate special reports. When these pictures are mounted on cardboard and filed they furnish valuable illustrative material for years to come.

The making of lantern slides provides an excellent form of pupil activity. An outfit from the Keystone View Co., Meadville, Penn., is a great aid to the making of pupil-made slides. Blank slides of ground glass and colored pencils, cellophane sheets, especially prepared glass slides and bottles of various shades of transparent ink are included. These slides may be cleaned and used repeatedly. They lend themselves to many studies, particularly in the field of botany.

Many schools have quite complete collections of slides

[7]Hansen, J. E., "Why We Should Use Pictures in Teaching," Junior-Senior High School Clearing House, December, 1930, p. 205.

[8]Editorial in Junior-Senior High School Clearing House, December, 1930, p. 194.

which may be obtained from several companies. They are among the oldest and most useful of the visual aids.

Microscopical slides of plant and animal tissues may be projected by means of a micro-projector. With young pupils who are inexperienced in using the microscope, the slide thrown on a screen is an excellent means of familiarizing pupils with cell structures. While it is doubtless desirable that pupils in elementary biology should do some individual microscopic work, much time is often wasted because they do not know what they are supposed to see. If a slide can be projected on a screen and the instructor can point out the different kinds of cells in a cross section of a stem, for example, pupils may then use their microscopes with far greater efficiency. The description in SCHOOL SCIENCE AND MATHEMATICS for October, 1930, of a microprojector used in a biology classroom in Munich is replete with suggestions.[9]

The film slide, film strip or picturol as it is variously called is in many ways superior to the glass slide. The film slide is among the most inexpensive of the various kinds of projected pictures, and schools which find the moving picture out of the question, find it a welcome substitute. Many 35 m. m. and 16 m. m. moving picture films have been reproduced as film slides. "Interdependence of Plant and Animal Life" from Bray Productions, Incorporated, is an excellent summary of the usual unit on photosynthesis. "Functions of Living Things" from the Spencer Lens Company is another example of the film slide that is adapted to biology. The well-known moving picture "How Life Begins" has been reproduced in a series of film slides.

The United States Department of Agriculture furnishes some valuable film strips that have been prepared from lantern slides. Especially noteworthy are the ones on plant propagation, plant and insect diseases of garden and field crops.

Mention should be made of the film strips distributed free by the Metropolitan Life Insurance Company. These film slides supplement their booklets in the Health Heroes Series.

9Black, N. Henry, "The Use of the Projection Microscope in The Teaching of Biology," SCHOOL SCIENCE AND MATHEMATICS, October, 1930, pp. 737-747.

The Nature Study film strips issued monthly by The San Jose State College, San Jose, California, provide seasonal material that may be adapted to biology classes. As with so many forms of the visual aids, these film strips may be adapted by a skillful teacher to a class in high school biology or to one in elementary science or nature study. The presentation of the material will determine to a large extent the success or failure of the lesson. The subjects are chiefly of California plants and animals. It is to be hoped that other sections of the United States will be represented as is California in these Nature Study film strips.

With a good delineascope these film strips or picturols give almost as clear a picture as the more familiar glass slide and have the decided advantage of being non-breakable and far less expensive. "The Life History of The Bullfrog" a new production of the General Biological Supply House, Chicago, in a film slide is listed at $3.75 and in a lantern slide set at $18.00. To the school with a limited budget the film slide offers a maximum amount of material at a minimum expense. There are situations in which it is superior to the moving picture. During a review any particular slide may remain on the screen as long as is desired for discussion or questioning by pupils or teacher.

The still film produced in Los Angeles is similar in purposes and uses to the film strip. Some of the subjects classified under nature study may be used in biology classes. The construction kit offered by this company is a real contribution to the development of pupil activity in the making of pictures to be projected in the classroom or in assembly. This material has been used with considerable success in some of the Los Angeles schools, but it is not as conveniently handled as the individual glass slides.

The moving picture arouses pupil interest as probably no other form of the visual aids can do. There are situations in which the movie shows that which cannot be explained by any other means. Life processes may be shown by means of animated diagrams, X-ray or motion microphotography. A class in the middle states, for

example, may view a film entitled "Some Seashore Animals" and have the experience, vicarious to be sure, of witnessing these animals moving, feeding, fighting in their natural environment. When the desirable excursion is impossible or impractical the moving picture is often an excellent substitute.

Nothing finer than the Eastman Teaching Film Library has been made. The widely read columnist, Arthur Brisbane, visited the Eastman factory last April and after viewing some of the educational pictures wrote: "The greatest teaching genius could not in 10 hours convey to the mind what these pictures can convey in 15 minutes. As Ruskin testified long ago, photography in itself is the greatest force for education. With motion and color added, it will shorten education as stenography has shortened writing."[10]

Teachers who have used films as a teaching device have discovered that they are not a substitute for supervised study, experiment, discussion and review. Dr. T. E. Finegan gives a clear and sane statement relative to the place of the films in the schools. "This type of film is, therefore, simply a classroom agency in the hands of the teacher. It is to be used by him when needed, in the same way as other classroom aids or apparatus; it is not a substitute for the teacher or the textbook. It is just a tool to clarify his work and make it more impressive. It should be adapted to specific lessons and to definite grades."[11]

Among the Eastman Films valuable in what we may term human biology are the following subjects edited on the unit basis: "The Blood," "Circulation," "Circulatory Control," "Body Framework," "Breathing," "Digestion," "Food and Growth," "Muscles," "Tuberculosis and How It May Be Avoided," and "Bacteria." In the realm of Natural History are the following: "Termites," "Microscopic Animal Life," "Life History of the Yellow Fever Mosquito," "Game Birds," "Birds of Prey," "Birds of the Seacoast," "Luther Burbank," "Wild Flowers," "Some

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[10]Brisbane, Arthur, Rochester, N. Y., Journal and Post Express, April 17, 1931.

[11]Fingan, T. E., "An Experiment in The Development of Classroom Films." Reprint from "Transactions of The Society of Motion Picture Engineers," Volume XI, Number 31, 1927, pp. 545, 563.

Water Insects," "Rocky Mountain Mammals," "Some Larger Mammals," "Some Seashore Animals," and "The Living Cell."

Persons who have enjoyed the illustrated lectures of Mr. Arthur C. Pillsbury will be interested to know that his films are available for school use. Among them are assorted microscopic pictures, including the mold study, circulation in a leaf, the germination of the pollen grain, and so forth. He also offers lapse time pictures of under sea life and the life story of the termite as well as wild flowers of the Sierra Nevada mountains in full color.

The UFA Films, Incorporated, 1540 Broadway, New York City, has produced many biological films which may be had with spoken lectures. Many of these splendid films deal with large biological principles. They are in a class by themselves—superior in every respect. Among them are: "Partnership Under the Sea," a study in commensalism; "Traps for Insects," insect eating plants and animals; "The First Law of Nature," the snake's struggle for existence; "The Survival of the Fittest"; "The Cycle of Life" which shows the interchangeability of matter; "The Bloods" which shows human, bird's and frog's blood and "The Breath of Life" which shows bubbles of gas escaping from the stomata.

The University Film Foundation of Cambridge, Mass., has produced some noteworthy films. Among them are "The Nesting of The Sea Turtle," "A Tropic Garden," "Elementary Animal Forms," and "Simple Animal Forms."

This paper would not be complete without some mention of the newest of the visual aids, sound films. Portable machines for classroom use have been developed by Bell Howell Company, The Victor Animatograph Corporation and others. The films with sound accompaniment in the form of large discs have been produced by UFA Films, Incorporated and The University Film Foundation. It would seem that the sound picture used in science classes will not have the values that it will in music, the language and in English classes. Biology teachers have been successful to a great extent in escap-

ing from the lecture method, and these sound films are rather formal discussions synchronized to explain the film as it appears on the screen. When explanation is necessary it is far better that the teacher should furnish it. She knows the background and capacities of her group and a word here and there where really necessary is more helpful than a continual barrage of explanation, part of which must be confusing and distracting to young pupils. The projection apparatus is so expensive that sound pictures will doubtless make their way slowly into all schools except those in large or richly endowed communities.

As a classroom teacher whose work during the past eight years has been vitalized and made more pleasurable and interesting to herself as well as to her pupils because of a generous and, I hope, a wise use of the different types of the visual aids described in this paper, I wish to urge all science teachers who have not already done so to use these materials until they too become enthusiasts. Boards of education will provide these visual aids as they are demanded or better requested. It is to be hoped that they will be provided as liberally as maps, texts and reference books, and laboratory apparatus have been in the past. It is my belief that one well-edited film is fully as valuable, if not more so, to a class than a set of supplementary texts. The cost is often about the same. It will be a step toward better teaching to see to it that administrators appreciate the amount of pupil time that these visual aids may save, as well as the fact that these materials arouse interest as nothing else can do. Thus the economy of visual aids in biology teaching is at least two-fold.

NO CHEMICAL ELEMENTS HEAVIER THAN URANIUM, SCIENTIST CONCLUDES

Hope that there are more than the 92 chemical elements now known is not bolstered up by theoretical studies made by Dr. V. V. Narliker, University of Cambridge scientist. Investigating the highest atomic number in the light of wave mechanics, Dr. Narliker finds that the highest possible atomic number seems to be 92, that of uranium, heaviest known element, and not 137 as previous studies had suggested. His report was made to "Nature," leading British science weekly.—Science Service.

HOW THE LAST TWO ELEMENTS WERE FOUND

Steps in the Discovery of Virginium (No. 87) and Alabamine (No. 85) Which Complete the List of Ninety-two Chemical Elements

BY HANOR A. WEBB,

George Peabody College for Teachers, Nashville, Tenn.

The Periodic Table of the Elements is now full. The numerous gaps therein which Mendelejeff (1834-1907) the Russian discovered—if gaps may properly be called discoveries—no longer exist. One by one they have been filled by the patient research of scientists, usually chemists, but physicists at times. When the X-ray spectra on the photographic plates of Moseley (1889-1915) tagged the atoms with numbers, but ninety-two positions on his scale seemed possible between the lines given by hydrogen—the lightest element—and uranium—the heaviest. There may be undiscovered elements heavier than uranium, but there are none still hidden of lighter weight, if evidence presented within recent months has been rightly interpreted.

The existence of Element 87 and Element 85 is reported by Dr. Fred Allison of the Alabama Polytechnic Institute, Auburn, Alabama, in recent issues of *The Physical Review* and *The Journal of the American Chemical Society.* So confident is he of the validity of his work that he has assumed the discoverer's right to name his finds, and suggested the names Virginium (Va) and Alabamine (Am) for them. They honor the state in which Dr. Allison was born on July 4, 1882, and the state in which his search has come to a successful conclusion.

THE LAST SEVEN

Ten years ago there were seven unfound elements, marked by gaps on the published Periodic Charts. (Some teachers of chemistry have not written in any of these gaps to this good day; they "keep behind" at least a decade, if not farther!) Then in rapid succession chemical research bore fruit, as follows:

In 1923 element 72, hafnium (Hf) was discovered by two Danes, Coster and Hevesey, and given the ancient name of their capital city known to you as Copenhagen.

In 1924 element 43, masurium (Ma), and element 75, rhenium (Re) were identified by Dr. Noddack of Germany, and given the names of ancient provinces.

In 1926 element 61, illinium (Il) was the first to honor an American chemist, being found by Dr. B. S. Hopkins of the University of Illinois, and patriotically named by him in honor of his school and state.

In 1927 element 91, protoactinium (Pa), was announced by Dr. Grosse of Berlin. Its name means "ahead of actinium," and as one of those striking radioactive elements it breaks down endlessly, producing the three kinds of rays and element 89, actinium (Ac), as products of the wreckage.

Under date of January 11, 1930, Drs. Fred Allison and Edgar J. Murphy announced the detection of element 87,[1] virginium (Va), in pollucite (Latin, "Pollux"), a cesium-aluminum silicate ($H_2Cs_4Al_4Si_9O_{27}$), and in lepidolite (Greek, "scaly"), a lithium-aluminum member of the mica family ($HKLiAl_2Si_3O_{10}F$). On April 3, 1931, he and three associates (Edgar J. Murphy, Edna R. Bishop, Anne L. Sommer) announced element 85,[2] now alabamine (Am), in monazite (gaslight mantle) sand from Brazil, potash from Germany, sea water, and several other sources.

When we read in his announcement that "the method employed is sufficiently delicate to detect less than one part of a compound in 10^{10} parts of water" we may wonder what the details of this amazing analytical method may be. It is called "a magneto-optic method of analysis" by Dr. Allison, its inventor. The apparatus used by him has been gradually developed through fully ten years of experimentation, and it makes use of principles discovered fully a century ago. Few indeed are the prizes of physics or chemistry that are not gained without patient labor!

A Light that Twists

Jean Baptiste Biot (1774-1862), a patient Frenchman, worked for forty-seven of his eighty-eight years in studies upon the strange behavior of a beam of light that, when reflected from a mirror at a certain angle, possessed waves that vibrated in but one direction. This is called "plane polarized" light. Compared to ordinary light, it is similar to the contrast between orderly lines of soldiers and a milling crowd. Biot and his fellow-workers found that the

[1] *Physical Review* 35, 285 (Feb. 1, 1930).
[2] *Physical Review* 37, 1178 (May 1, 1931).

"plane" of the wave vibrations could be twisted, just as you would twist a long, tightly-stretched ribbon. This came about when the polarized light passed through tubes containing certain clear liquids, chiefly organic compounds or their solutions, such as the fruit acids and sugars.

This phenomenon became known as "optical rotation" because it could be observed only in an optical instrument —the polariscope—in which light became polarized on passing through a specially cut calcite prism, passed through the tube of liquid, then was measured as to the slant of its plane by another calcite prism, which must be turned through a definite angle before the light would shine through again.[3]

The cause of the twisting of the plane when polarized light passes through a solution remained a mystery until 1874, when two young chemists within a month of each other proposed an acceptable theory, which each had thought out unknown to the other. Queer things happen at times in science! Jacobus Henricus van't Hoff (1852-1911) of Holland, and Joseph Achille Le Bel (1847—) of France discovered that every substance causing optical rotation possessed an atom of carbon upon which a *different* atom or radical was fastened to each of the four valence bonds. The unbalanced nature of such a molecule gave the name *assymmetric* (Greek, "without balanced measure") *carbon* to the central atom.

Other assymmetric atoms have been discovered; nitrogen, tin, sulfur, selenium, phosphorus, silicon, chromium, and cobalt have served as similar centers for optically active substances.[4]

A Magnetized Light Ray

An ordinary beam of light is wholly unaffected by a magnet. A polarized ray, however, suffers a twisting of its plane in passing through a strong magnetic field. Transparent liquids, whether they contain assymmetric

[3]These prisms were invented in 1828 by William Nicol (1768?-1851?) who spent practically his entire life in his small laboratory in Edinburgh, Scotland. In practice the Nicol prisms of the polariscope are read in the "crossed" position, in which no light passes through, since it is easier to detect the point of greatest darkness than the point of greatest light. The better instruments, however, are constructed so that two fields of half-shadows, or gray, are made equal in tint for a reading.

[4]Glazebrook, Sir Richard, *Dictionary of Applied Physics*, page 349, (The Macmillan Co., London).

elements or not, acquire this property of rotating the plane if the light passes through the liquid in the direction of the lines of force. This condition is easily attained by placing the liquid in a tube surrounded by a coil of wire.

This important discovery was made by the great English physicist and chemist, Michael Faraday (1791-1867) in 1845. It is called "the Faraday effect."

About ten years ago Dr. Fred Allison, at the University of Virginia, began working on the problem to determine whether the Faraday effect was instantaneous—whether the twisting of a beam of polarized light passing through a tube occurred at the precise moment that the magnetic field began, and whether it suspended on the instant that current ceased in the coil. He invented an apparatus of ingenious design; little did he suspect at the time that this equipment would enable him to discover the last two chemical elements!

The First Magneto-Optic Instrument

At the front end of the instrument was a spark between zinc electrodes. Behind was a lens to make the rays parallel; then a light filter to produce light of nearly one color, or wave-length. This light passed through a Nicol prism and became plane polarized.

Next came two tubes, with clear glass ends. Each was surrounded by identical coils of wire, wound in opposite directions. One tube was directly behind the other, and could be moved closer or farther back. Side-necks made it possible to fill each tube with any liquid desired.

Behind the tubes was another Nicol prism. This, when turned, would detect by its position any twisting of the polarized ray, which was observed through an eyepiece. The two Nicols were "crossed," giving a minimum of light on the "zero" readings.

The same high-tension current that produced the spark also caused the magnetic fields within the liquids that filled the tubes. With the same liquids in each, the twist caused by one winding would be neutralized by the other winding of opposite direction. There should be no twist of the ray, then, except for this tiny "error"—the fact that the light could not pass the distance of a few inches between the front and rear tubes instantaneously. He adjusted the

length of the wires leading to the rear tube so that the electric impulse—even as the light—had to travel an additional distance. This "wire path" for the current would be the same as the "air path" for the light. (Dr. Allison later discovered that electricity flows through a wire with but 96 or 97 per cent the speed of light.) Then, using the same liquid in both tubes, the eyepiece would show no light when the second Nicol was turned to zero, or precisely "crossed."

Two different liquids, however, gave striking results. When the apparatus had been "set" with carbon bisulfide in both tubes, then carbon tetrachloride was placed in the second tube, and it was necessary to move it back 32 cm in order to obtain a minimum of light in the eyepiece. There was a "lag of the Faraday effect" in carbon tetrachloride, this being greater than any lag in the carbon bisulfide by an interval of time necessary for light to travel through 32 cm of space. Now the speed of light is known with sufficient accuracy to warrant the simple computation that the difference in the lags of the two liquids is 32 cm/300,000 km (approximately) of one second, or about 1.1×10^{-9} (billionths) seconds.

In their report[5] of this investigation, Beams and Allison gave the lag of ten liquids behind carbon bisulfide. One was water; one was hydrochloric acid; the rest were simple organic liquids. This work had accomplished two things: (a) discovered the "lag of the Faraday effect"; (b) devised a method of measuring time in intervals of billionths of a second.

"The Twinkling of an Eye"

What words do you use to imply extremely short intervals of time? "Three shakes of a lamb's tail?" "The dart of a toad's tongue?" "One flap of a humming bird's wing?" Even in serious measurements the wave of a tuning fork's stylus, the shrill tone of a carrier wave, are almost vanishing periods of time. These become almost aeonic in comparison with Dr. Allison's time-intervals determined with the magneto-optic device. Various improvements were soon reported,[6] and a precision of 2×10^{-10} (one

[5] *Physical Review* 29, 161 (January, 1927).
[6] *Physical Review* 30, 66 (July, 1927); ibid, 31, 158, (January, 1928); ibid, 31, 313 (February, 1928).

five-billionth) of a second was reached. The effect of temperature on the lag was tested, and found to be negligible. The changes with different wave-lengths were measured, and the shorter waves found to be subject to longer lags. The speed of an electric impulse along a wire was found to be 96 per cent that of light in air. Most important of all, it was found that two liquids might be mixed in the tube, yet each would retain its own lag unchanged. There might even be chemical union, such as an organic acid and an alcohol to form an ester, yet the respective lags would remain; the ester did not produce a new "minimum" of light in the eyepiece.

THE "SURPRISING RESULT"

Early in 1930 Dr. Allison announced[7] "a surprising result" in connection with his measurements. He could dilute his liquids until there was less than one part in 10^{10} (ten billion) before the characteristic "minimum" of the light would disappear. "This method thus affords a very sensitive and rapid means of chemical analysis," he wrote.

Sensitive indeed! A few months later he could report that "the results show that about 1 part in 10^{11} of the solvent can be detected."[8] The effect of a bit of salt, for example, could be observed when one hundred billion times as much water had been added to it. This is about the same as dissolving one teaspoonful of salt in 125,000,000 gallons of water, which would fill a tank as big as a skyscraper 100 feet wide, 100 feet long, and 160 feet (over 15 stories) high!

Dr. Allison then began to measure the "minima" of a large number of nitrates, chlorides, sulfates and hydroxides in solution. He found that only a powerful microscope could detect the existence of as small an amount of matter as he could find. A good chemical balance will weigh 1/10,000 of a gram with accuracy, and the best of them swing with 1/400,000 of a gram. The spectroscope detects the presence of a metal if but 1/3,000,000,000 part of it is there; this has been considered the chemist's most delicate tool for analysis. A good microscope will make visible a

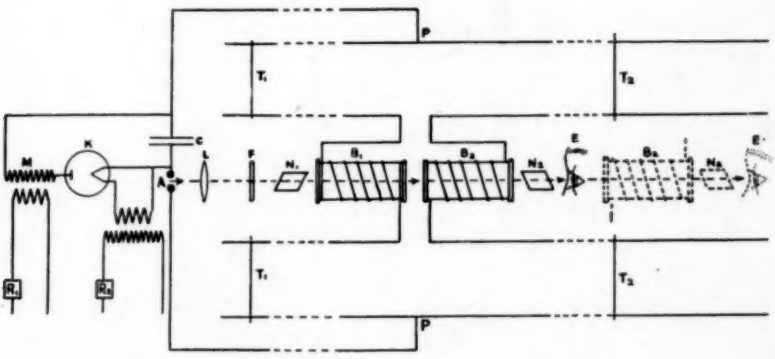
[7] *Physical Review* 35, 124 (January 1, 1930).
[8] *Journal of the American Chemical Society* 52, 3803 (October, 1930).

bit of matter 1/1,600,000,000,000 of a gram in weight.[9] Dissolve this tiniest speck that one could see with high powered lenses in twenty drops of water, and the magneto-optical apparatus would make it possible to report, "It is there!"

FINDING ELEMENT 87

"Element 87 is peculiarly well placed in the periodic table for detection by a new and very sensitive method recently reported by us" was the first word regarding the employment of the magneto-optic method by Drs. Allison and Murphy early in 1930.[10] They obtained pollucite and lepidolite ores from the Research Laboratory of the General Electric Company (see formulas earlier in this article) and converted the metals therein into chlorides, sulfates, nitrates, and hydroxides. In each case they found minima at points on their scale which corresponded to "an element of the atomic weight and valence ascribed to eka-caesium. . . . The work is still in progress."

THE "LATEST MODEL"



In their next report[11] Drs. Allison and Murphy gave a description of their improved magneto-optical apparatus. A kenetron tube (K) and sundry transformers supply the high-voltage discharge at the spark at A. From this point the light passes through a converging lens (L); filter (F) to produce nearly monochromatic light; polarizing Nicol (N-1); two improved cylinders, having the same axis,

[9] Aston, *Journal of the Franklin Institute*, 193, 583 (1922).
[10] *Physical Review* 35, 285 (February, 1930).
[11] *Journal of the American Chemical Society* 52, 3796 (October, 1930).

wound oppositely by equivalent helices of wire, the first tube being stationary (B-1), the second movable (B-2); an analyzer Nicol (N-2), movable with tube B-2; an eyepiece (E). The movements of B-2 are measured upon a scale of distance, equipped with a vernier. This is called the "light-path scale."

The current passes through two circuits, each of which is in parallel with the other and with the spark gap. By means of movable "trolleys" (T-1, T-2) each circuit can be varied in its length. The windings around the cylindrical cells are precisely equal and of opposite direction, as already described.

It will be apparent by a study of the diagram that a race is on between the beam of light and the current of electricity. Making allowance for the slight difference in their rate (speed of electricity through wire is 96 to 97 per cent of speed of light through air) the lines of magnetic force will be produced within the liquid at the same instant the polarized light generated by the same power arrives to be twisted.

The lag in the Faraday effect, therefore, must be compensated by one of the following adjustments:

(a) Moving the second tube (B-2) back, so that the light ray must travel enough farther to delay its entrance by a time interval equal to the lag. This is the "air path" measurement.

(b) Shortening the circuit leading to the second tube by moving the trolley (T-2). The magnetic field is thus induced in B-2 earlier than in B-1 by a time interval equal to the lag. This is a "wire path" measurement.

(c) Lengthening the circuit leading to the first tube by moving the trolley (T-1). The magnetic field is thus induced in B-1 later than in B-2 by a time interval equal to the lag.

(d) Combinations of the above methods. By such manipulations the movement of the trolley (or trolleys) becomes a coarse adjustment, and the movement of the second tube a fine adjustment. Since all of these adjustable parts have scales and verniers, very accurate readings are possible.

FINDING A "MINIMUM"

In brief, the operation involved in obtaining a reading of the lag of the Faraday effect in a given liquid is as follows:

(a) With tubes removed, the Nicols are precisely crossed so that no light passes from the spark.

(b) With both tubes in place, and filled with carbon bisulfide, the trolleys are adjusted so that the rotation in the first tube is precisely compensated in the second. This takes care of the slight difference in time required for the light ray to reach the second tube which is a few centimeters behind. The annulment of rotation is observed in the eyepiece by a complete extinguishment of the light ray.

(Recall at this time that the coils around the tubes are equal in length and opposite in direction, therefore "the Faraday effect" or twist of the polarized ray due to lines of magnetic force is equal and opposite, therefore compensated.)

(c) Carbon bisulfide is removed from the second tube, and replaced by the liquid under examination. Since it happens that the lag of the Faraday effect is less in carbon bisulfide than in any other liquid studied so far, the adjustment must be made for a greater lag. This is done by the methods previously described: moving the second tube back (102 cm for toluene, using a certain wave-length); or shortening the circuit leading to the second tube (99 cm for toluene); or lengthening the circuit leading to the first tube (99 cm for toluene).

(d) At the eyepiece the observer watches for the point at which the least light passes through. When different liquids are in the two tubes darkness will not be complete, but will reach a minimum of light. This is due to a relationship between the amount of rotation, the magnetic field causing it, the length of the path through a liquid, and a constant—called Verdet's constant—which is different for each liquid.[12]

(e) If the minimum is ascertained by the "air path" method, it is then checked by the "wire path" method.

(f) Readings are in terms of centimeters of displacement (of tube or of trolley) along a scale. This is readily

[12]The formula is: *rotation = Verdet's constant × strength of magnetic field × length of the path traversed in the field.* See John K. Robertson, *Introduction to Physical Optics* (Van Nostrand, 1929), page 308.

converted into terms of time interval upon dividing the distance traversed by light or electricity in one second by the distance of displacement.

Finding Element 85

"When it rains, it pours" is a maxim that sometimes applies to scientific discovery. Following his announcement of January 11, 1930, concerning the detection of element 87 by the magneto-optic method came news that the last remaining gap upon the periodic chart was also filled. On April 3, 1931, Drs. Allison, Murphy, and their associates (Edna R. Bishop, Anna L. Sommer) published[13] curves and figures showing that minima found could only be due to element 85.

Element 85 was found in sea water, fluorite, apatite, Brazilian monazite sand, Stassfurt kainite, commercial potassium bromide, hydrobromic and hydrofluoric acids. Being the heaviest member of the halogen family, it was made into "85 acid"—formula, H85—also salts which by the same terminology were Li85, $Al(85)_3$, $Mg(85)_2$, $NH_4Fe(85)_4$, $Fe(85)_3$, $Ca(85)_2$, Na85. The greatest abundance of these in any of the solutions was 1 part in 10^9. Attempts to concentrate the element in the form of a Li85 salt were begun at once.

Confirmation by X-Ray Spectrum

Dr. Allison had announced his discovery of element 87 on January 11, 1930. On September 14, 1931, Drs. Jacob Papish and Eugene Wainer of Cornell University made public their final success in detecting this same element by the method which has proved the existence of the more recent finds—the X-ray spectrum. Every modern chemistry text describes the work of H. G. J. Moseley (1889-1915), brilliant English physicist, and gives diagrams of the X-ray spectra which he discovered in which every element has a specified position according to its "atomic number." From the mineral samarskite Dr. Papish was able to photograph X-ray spectral lines in the proper position to indicate that element 87 was present.

In their published announcement[14] Drs. Papish and

[13] *Physical Review* 37, 1178 (May 1, 1931).
[14] *Journal of the American Chemical Society* 53, 3818 (October, 1931).

Wainer injected an unfortunate note of competition with Drs. Allison and Murphy to receive the honor of being considered the discoverers of element 87. They questioned Dr. Allison's work by assuming that his minima were due to mixtures of complex chloride ions of tin and rhenium in the minerals used. They stated that they would name element 87 as soon as they obtained some additional evidence from the X-ray.

NAMING THE "BABY ELEMENTS"

Dr. Allison was very prompt in answering this objection. Under date of November 5, 1931, he and his helpers published[15] results with not only the chlorides of 87 (which Dr. Papish had tested) but also nitrates, sulfates, and hydroxides. Each compound gave its proper minimum in the apparatus.

They then made readings of tin and rhenium chlorides. They oxidized the tin salt with sulfur dioxide, and the minima disappeared from their accustomed places. They oxidized the rhenium salt with perchloric acid, and its minima were altered. The same treatment for 87 chloride did not change the minima.

They diluted solutions of the ores in which three distinct minima for tin, rhenium, and 87 chlorides were to be seen. At a certain point the 87 chloride could no longer be detected, but the tin and rhenium chlorides, being present in larger amounts, were still to be measured.

"Since we have found nothing else which might give the minima attributed to compounds of 87 and since these minima persist after treatment with acids, bases, oxidizing and reducing agents, we conclude, as previously announced, that these minima are due to element 87." Thus convinced, Dr. Allison assigned the name "Virginium" and the symbol Va to element 87.

Further confirmation came when Dr. J. L. McGhee of Emory University, Atlanta, Ga., using the magneto-optic apparatus, made examinations of the minerals with which Dr. Allison worked, and found the element present.

Element 85 was named on November 25, 1931, when Dr. Allison and his associates announced[16] a considerable con-

[15] *Journal of the American Chemical Society* 54, 613 (February, 1932).
[16] *Ibid*, 54, 616.

centration of it from Brazilian monazite sand, which they made 160 times stronger than in its natural occurrence. They made a series of acids, corresponding to the oxygen acids of chlorine, and the corresponding salts. They considered the existence of the element so firmly established that the name "Alabamine" and symbol Am was published.

"Hail virginium, chemical element 87; hail alabamine, chemical element 85—last of earth's fundamental building blocks to be christened!" Thus chants the special writer for "Science Service"[11] in releasing these names into the channels of news. Eka-caesium and eka-iodine are no more. Teachers of chemistry must now discourse on the six isotopes of virginium, and on its various salts. Students must now learn of hypoalabamites, alabamites, alabamates, peralabamates, as well as of alabamides, hydroalabamic acid, and the like. Research chemists will discover much that is new as the years go by, but they will never find another element between hydrogen and uranium. Virginia, the state of Dr. Allison's birth on July 4, 1882, and Alabama, the state of his triumphs of January 11, 1930, and April 3, 1931, have been honored, and the nation rejoices that again the privilege of discovering and naming an element has come to a citizen of the United States.

INTERNATIONAL MATHEMATICIANS CONGRESS, ZURICH, SWITZERLAND, SEPT. 4-12, 1932

An International Mathematicians Congress will be held in the Federal Institute of Technology at Zurich from September 4 to 12, next. The scientific part of the program will consist of a large number of general lectures and section meetings. The lectures are intended to provide a complete survey of the present standing of mathematics. Eminent lecturers have, of course, been secured.

The section meetings are intended for briefer discussions of the results of new investigations. The following sections are foreseen: 1. algebra and calculus; 2. analysis; 3. geometry; 4. insurance mathematics; 5. astronomy; 6. mechanics and mathematical physics; 7. mathematical-technical science; 8. philosophy; 9. history; 10. pedagogy.

In addition to these scientific meetings, social gatherings and excursions to different points of interest in Switzerland are being planned, so that the mathematicians' sojourn at Zurich will be made pleasant and interesting in every respect. Mathematicians from all over the world are cordially invited to participate in this event.

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[11] *Science News Letter* 21, 83 (February 6, 1932).

THE ESSENTIAL TECHNICAL VOCABULARY OF PLANE GEOMETRY

BY S. L. PRESSEY, L. C. PRESSEY, AND R. C. ZOOK,
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I. PURPOSES AND TECHNIQUES OF THE INVESTIGATION

Even a casual glance at a textbook in plane geometry should convince one that there is a considerable burden of technical terms. Presumably, all these words have some usefulness, but it seems reasonable to suppose that there must be a central group of technical words that are of more fundamental significance than the others. It was the object of the present study to determine which of the several hundred specialized words contained in the average geometry textbook constitute the really essential "core."

The first technique consisted of (a) a frequency count of technical words in three standard texts in geometry. A total of 943 different technical words was found, varying in frequency from one appearance only in all three texts to 696 appearances in the three. Those terms occurring 10 times or more per book were selected for further study. There were 169 such words.

These terms were further considered in the light of (b) the ratings by 38 geometry teachers as to the importance of each word for teaching and (c) a consideration by the writers as to the actual "technical-ness" of each word, as to its general social value outside of specialized work in geometry, and as to its usefulness in other subjects—such as mechanical drawing, physics, etc. In this last connection, frequency counts[1] of the mathematical words appearing in other subjects than arithmetic, algebra and geometry were consulted. After eliminating those words that seemed not technical at all (such as "edge," "size," "reason") and those that seemed to the teachers to be unimportant for a first course in geometry (such as "postulate," "octagon," "tetrahedron") there remained only 77 terms. These were admittedly essential to geometry, but it appeared that many of them had little general value outside the subject. It was, therefore, decided to keep the entire 77, but to put a star in front of those that seemed to have little practical value outside the classroom. These terms are presented below.

[1]For instance, Pressey, L. C. "The Needs of College Freshmen in the Field of Mathematics," *School Science and Mathematics*, XXX:238-243, 1930.

II. Results of the Investigation

The terms decided upon, as described above, have been grouped so as to bring out related meanings.

Section I: Angles and Triangles

angle#	*corresponding angle	*equiangular triangle
acute angle	bisector	*isosceles triangle
*obtuse angle	*common angle	hypotenuse#
*straight angle	adjacent	base#
bisect	*opposite angle	*congruent
equal#	triangle#	altitude#
*supplementary	*included angle	vertex
degree#	*equilateral triangle	vertices
right angle	right triangle	similar
		*external angle

Section II: Straight Lines

perpendicular	intersect	*locus
parallel	equidistant	ratio#
*transversal	midpoint	proportion#

Section III: Polygons

rectangle#	*hexagon	*polygon
circle	*trapezoid	*regular polygon
*parallelogram	*quadrilateral	equivalent
square#	diagonal#	area#
*rhombus	perimeter#	symmetry

Section IV: Circles

arc	diameter#	*tangent
center	*inscribe	*secant
chord	radius#	circumference#
*circumscribe	radii	pi#

Section V: Terms used in presenting theorems

axiom	corollary	respectively
*construction	plane	proof
*theorem	surface	given
proposition	geometric	prove

It is worthy of comment that so many words are so highly special as to have little general value. This situation is truer of geometry than of either algebra or arithmetic. Its fundamental concepts do not seem to enter into the ordinary person's daily life whether or not he goes on into more advanced work, unless his major field is mathematics.

III. Practical Value of the Results

The list by itself should prove of service; however, in order that the geometry teacher may make the best use of these results as a regular classroom practice, a test calling for recognition of each of the concepts has been made. Items from the test cannot be here reproduced because figures are required for the answering of the questions. It

This symbol means that the word appears in the arithmetic list, also.

may be said, however, that in no case is a verbal definition called for. For instance, a student is asked to pick out which of a number of possible angles is the most acute, which of several triangles is isosceles, or which segment of a given line is the longest, etc.

Results of another investigation have shown acquisition of these terms to be slight and retention poor[2]. If the teacher of geometry wishes to improve mastery of her subject, she will do well to see to it that her students really acquire the fundamental vocabulary, without which the learning of such a technical subject as geometry is practically impossible.

ILLINOIS ACADEMY OF SCIENCE

Hundreds of scientists from all parts of the State will assemble on May 6 and 7 for the twenty-fifth annual meeting of the Illinois State Academy of Science, which will be held this year at the University of Chicago, bringing together the State's outstanding minds in the field of Anthropology, Agriculture, Botany, Economics, Geography, Geology, Medicine and Public Health, Physics and Chemistry, Psychology and Education, and Zoology.

The two-day sessions will comprise both general and sectional meetings as well as special inspection trips to the New Oriental Museum at the University of Chicago, the Field Museum of Natural History, the Adler Planetarium, and the Shedd Aquarium.

One of the high spots of the scientific gathering will be the address of the retiring president—Dr. Fay-Cooper Cole, noted anthropologist of the University of Chicago. His address on "The Coming of Man," will be delivered at 7:45 p. m. on Friday, May 6, immediately following the annual dinner of the Society, which will take place at the Shoreland Hotel, near the University campus.

The meeting will officially begin at 9:30 a. m. on May 6, when Robert Maynard Hutchens, president of the University of Chicago, delivers the address of welcome, opening the general sessions at Mandel Hall, to which the public will be admitted.

Dr. Cole will respond to the address of welcome, and will be followed by Dr. M. M. Leighton, Chief of the State Geological Survey, who will speak on "Twenty-five Years of the Academy of Science."

The next speaker on the general program will be Dr. J. Harlen Bretz, of the University of Chicago. The title of his address will be, "The Glacial History of the Chicago Region."

Dr. L. E. Sawyer, Extension Forester, of the State Natural History Survey, will also appear on the general program, before the scientists scatter, to hold their sectional meetings for each of the sciences represented in the Academy. Dr. Sawyer will talk on "The National Forest Movement in Illinois."

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[2]See an article by L. C. Pressey and W. S. Moore, "The Growth of Mathematical Vocabulary from the Third Grade through High School" to be published shortly.

TESTING THE TEST-MAKERS[1]

By Leon Nordau Diamond,
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The practice of educational testing has gone through a series of unprecedented changes during the past decade; changes whose true significance, according to many, has yet to be ascertained. Such innovations as standards and norms to rate student performance more accurately have been introduced, while the traditional essay question has been transformed into such diverse varieties as the true-false, multiple-choice, and others; in short, testing might be said to have undergone a complete metamorphosis.

And yet, one would be more than foolhardy to assert that the old standards of testing have been invalidated by these changes. We might take as an instance in point the presence of unfairness in tests. Surely injustice to the student as the result of unfair tests is to be deplored as much today as yesterday? While the writer has no intention of embarking upon an abstract discussion of justice and injustice as they apply to the school, still it may be said that justice is the quality above all others which makes the greatest appeal to the student.

Although the precise extent of injustice which occurs as the result of using faulty educational tests is an undiscoverable quantity, this should not deter us from the attempt to discover, at least approximately, its prevalence in these measures. As a means of achieving this, it is necessary to examine these tests carefully, in this instance those of biology and general science, asking ourselves such questions as these: How fair are test-makers in demanding factual accuracy from the students being tested if, at the same time, they include erroneous items in these same tests? To what extent do the items making up a test succeed in measuring truths rather than half-truths? Is the adherence of these tests to an aim of science teaching such as "the acquisition of knowledge of scientifically accurate facts, principles, and theories," solely a matter of lip-service or has it played a more significant rôle?

These inquiries seem to be no more than fair when it is

[1]Paper given at meeting of the National Council of Supervisors of Elementary Science at Washington, D. C., Feb. 20th, 1932.

observed that while the knowledge of the student is subject to the higher review of such tests as he may be given, the test-maker is subject to no higher authority than himself. There is no agency that will compel him to submit to periodic examination and scrutiny as a means of discovering whether his knowledge of subject-matter is broad enough, is accurate enough, to permit him to construct examinations which will be sound measures of the student's knowledge. Certain it is that the teacher is no safe guide to rely upon for the choice of dependable tests. Else, how may we explain the popularity of certain tests in general science and biology which manage to enjoy a widespread sale in spite of the fact that they are permeated with flagrant inaccuracies.

And finally, the students; how often do they discover that the subject matter of the college and university is at variance that which they have been taught as true in the secondary school? All too frequently a student must spend valuable time in the acquisition of inaccurate subject matter, measured by inaccurate tests, which later must be painfully unlearned. And in most instances the opportunity to unlearn never comes.

To aid, therefore, these three classes of individuals—the test-makers, the teachers, and the students—the writer undertook to examine critically all of the available tests in general science and biology.[2] It was felt that while the statistical work involved in the preparation of these tests had been adequately cared for, the same could not be said for the more fundamental need of securing accurate test materials. As a result, the tests might be open to the charge of being faulty measuring instruments whose continued use in unmodified form might prove to be decidedly inimical to the best interests of all concerned.

Before going on to a critical treatment of some of the items appearing in 16 tests, it will be necessary first to give some brief explanation concerning the most common varieties of question which the reader is likely to encounter.

1. The True-False Type. In questions of this kind a statement is presented such as the following:

[2]Similar criticisms of some of these tests had been previously made by Dr. E. L. Palmer of Cornell University for which the writer is greatly indebted. Cf., *A Test of Science Tests*, Nature and Science Education Review, July, 1929, pp. 182-184.

The food calorie is the same as the heat calorie—*true*, false.[3]

The student is asked whether he believes this statement to be true or false. If true, he is expected to underline the appropriate term. Thus he is given credit if true has been underlined. Nevertheless, the item should be marked false inasmuch as the food Calorie (requiring capitalization) is 1000 times as large as the heat calorie.

2. The Multiple-Choice Type. Here, an incomplete statement is presented followed by several suggested answers, one of which correctly completes the thought of the initial statement.

Seeds are attached to the pod by means of a—1. peduncle; 2. *hilum;* 3. epicotyl; 4. micropyle; 5. auricle.[4]

The examinee is asked to underline that one of the four possibilities best completing the statement. While hilum is considered correct, it should be noted that it is merely a scar marking the place where the seed broke from the stalk (funiculus).

3. The Selection or Matching Type. In this type, two columns are usually present, one consisting of a list of terms and the other of a list of qualifying words or phrases. The student is asked to place the letter or number appearing before the initial list of words in their appropriate places preceding the words or phrases to which they apply.

A—Huxley B—Audubon C—Agassiz D—Malpighi E—deVries
O—For statements that do not apply.

62 B A noted student of American birds.
63 O Discovered circulation of blood.
64 D One of the early students of microscopic life.
65 A Noted as the champion of Darwin's theory.
66 E After experiments with primroses, announced the mutation theory.
67 C One of the first in the United States to emphasize the laboratory method of teaching.[5]

With regard to No. 66, it should be noted that De Vries experimented with the evening primrose; not with the ordinary primrose.

4. The Completion or Recall Type. Here we find usually a statement from which words or phrases have been omitted. Individuals taking the test are asked to fill in these omissions.

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[3]Giles, J. T., Thomas, S. M., Schmidt, H. M., *General Science* Examination, Eau Claire Book Company, Eau Claire, Wis., 1924. Test 11, question 16, Series A.

[4]Presson, J. M., *Presson Biology Tests*, World Book Company, Yonkers-on-Hudson, New York, 1930. Test 1, Form B, Part 2, No. 8.

[5]Oakes, M. E., and Powers, S. R., *Test of General Biology*, Teachers College, Columbia University, New York, Bureau of Publications, 1929. Form A, questions 62-67.

The largest and heaviest of the rodents is the—*beaver.*[6]

However, the beaver is neither the largest nor the heaviest of the rodents; the capybara of So. America exceeding it in size.

To return now to a consideration of the several kinds of errors to be found in these tests, it should be borne in mind that the classification which follows does not attempt to include all within its bounds. It is believed, however, that the majority of unsound test items will find their places somewhere within it.

In choosing examples of faulty items, the effort has been made to select representative errors which will be fairly indicative of others due to the same cause. Thus, the error appearing in the first item to be presented, namely; the false identification of combustion (or burning) with oxidation appears no less than eight times in five different tests.[7]

1. False Generalization. The most prolific cause of error in these achievement tests indubitably lies in the all-too-common tendency towards making false generalizations. When generalizations are properly made we are enabled to classify data more accurately. However, generalizations are quite dangerous if they ignore, as certain test items are prone to do, significant exceptions. The following are presented as typical instances of this sort of error:

a. Another name for combustion is—1. fusion; 2. melting; 3. freezing; 4. *oxidation;* 5. drying.[8]

The generalization we indulge in when we identify the process of combustion with oxidation, while common enough in text-book and test, has absolutely no scientific justification. Any act of chemical union between two or more elements which is accompanied by the evolution of heat and light is termed a combustion. Oxidation, however, is restricted to the combination of oxygen with any other element. This may or may not be accompanied by the emission of heat and light. If not, combustion cannot be said to have occurred.

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[6]Presson, J. M., *Presson Biology Tests,* Test 2, Form A, Part 1, No. 52.

[7]Cf. the writer's master's thesis, Cornell University Library, *A Critical Examination of Tests in High School Science,* 1931.

[8]Presson, J. M., *Presson Biology Tests,* Test 1, Form B, Part 2, No. 3.

b. Insects have the following number of pairs of wings—one, *two*, three, four, five.[9]

Some insects such as the members of the Diptera have but one pair of wings whereas others are entirely devoid of these organs.

c. Dressings on a wound should be removed and fresh ones applied—once a week, *once a day*, never, when the wound is well, every hour.[10]

There are no fixed rules for replacing dressings on wounds. Indeed, were all wounds, irrespective of their nature, to be dressed once a day, the consequences might well be serious. This generalization is decidedly at variance with the best medical procedures which make it an invariable rule for physicians to dress wounds according to their nature rather than in accordance with any fixed rule such as the above.

2. Failure to Keep Up With Scientific Progress. It is a commonplace to observe that the effect of science upon our knowledge is revolutionary. At least that is what we have been taught to believe. The new conceptions of knowledge which vitally affect the student must somehow become assimilated into a tradition-bound curriculum. This is necessitated by the fact, so often reiterated, that the student must somehow be prepared to play his part effectively in the out-of-school world. The process of assimilation of the new gains of science must be a continuous one, and this can best be facilitated through an attitude of wide-awake and critical scrutiny on the part of those who prepare our textbooks and tests of science.

a. Organic matter is matter which has or once had—*life*.[11]

While this may have been the prevailing notion before 1828 when Wohler synthesized urea in the laboratory, it can hardly be said to be true today when the organic chemist, as a routine procedure, builds up complex, organic substances without having recourse to "matter which has or once had life."

b. The best way to make impure water safe is to—let it settle, *boil it*, freeze it, use chemicals, do nothing.[12]

In the large-scale purification of water boiling is nowhere

[9]Dvorak, A., *General Science Scales*, Public School Publishing Company, Bloomington, Ill., 1924. Form R-1, No. 39.
[10]Dvorak, A., *General Science Scales*, Form R-1, No. 9.
[11]*Pittsburgh General Science Tests*, Dep't of Curriculum Study, Pittsburgh, Pa., 1929. Grade 9A, Part 2, Exercise 5, No. 1.
[12]Dvorak, A., *General Science Scales*, Form R-1, No. 4.

made use of, due to the huge expense involved, the resulting flat taste, and the technical skill required for its successful operation. Its place has been taken by such chemicals as liquid chlorine, ozone, and others which are far more efficacious.

c. The substance most used by man for fuel is—*wood*.[13]

Coal, rather than wood, has been the most widely used fuel ever since its introduction on a wide scale in the 19th century.

3. Mistaking Theory For Proven Fact. To distinguish between theory on the one hand and fact on the other is by no means an easy task. Notwithstanding this, the duty of the test-maker is clear. He must distinguish between the two where possible, and the working standard of truth which must be employed can be found only through a broad knowledge of the subject.

a. Birds migrate to find food and rear young in advantageous localities—*true*, false.[14]

While it is true that there are some ornithologists who would accept the above as being unequivocally true, there are many others who would not entirely subscribe to it. The following quotation is presented at some length to justify this view:

An explanation of migrational movement has been that of a seasonal change in food supply. . . . When with the approach of spring, the instinct for migration becomes paramount, as the food supplies of the broad equatorial belt are not sufficient to support the great host of young birds that will appear, the adults move out again to their summer homes in temperate or boreal regions. It may be argued against this that the tropical belt supports the migratory hosts when they have become grown, so it would seem that these same individuals might obtain sustenance there while in these same younger stages.[15]

b. Bees swarm:

1. *When a new queen appears in the hive.*
2. When the queen dies.
3. Every spring before the work of making honey is begun.
4. When they are disturbed.[16]

There are no fixed rules with regard to the swarming of bees owing to the diversity of conditions which may cause. As Dallas Lore Sharpe says:

If the bees followed an invariable rule in swarming, we would

[13]Presson, J. M., *Presson Biology Tests*, Test 1, Form A, No. 48.
[14]Giles, J. T., Thomas, S. M., Schmidt, H. M., *General Science Examination*, Test 13, No. 9.
[15]*Encyclopaedia Brittanica*, N. Y., 1929, 14th Ed., Vol. 16, p. 925.
[16]*Pittsburgh General Science Tests*, Gr. 9A, Part 1, Ex. 3, No. 1.

soon discover why, but there are no rules, no fixed conditions, no two swarming cases exactly the same.[17]

c. Dinosaurs and mastodons became extinct, for one reason, because they weighed too much—*true*, false.[18]

As yet, nobody knows definitely the reasons leading to the disappearance of these animals. Consequently, it would appear to be more in line with scientific practices to express such reasons in hypothetical terms especially since many dinosaurs were animals no larger than a house-cat.

4. Lack of Scientific Classification. The purpose of classification in science is to present an orderly scheme of things which will be comprehensible to the student in the secondary school as well as to the full-fledged scientist in his laboratory. To achieve this successfully, an extensive and well-organized plan of the science must be available to the test-author. If not, we may expect to find such errors as the following:

a. In the pollination of fruit trees, the pollen is usually carried by—birds, *bees*, man, animals.[19]

Since bees are animals rather than plants, an examinee underlining animals should also be considered as correct. This error is due to the unjustifiable restriction of this term to the mammals.

b. The name of the disease caused by rabies is *(hydrophobia)*.[20]

Rabies is not the cause of hydrophobia; it is merely a synonym for it.

c. Rust is a fungas disease attacking—1. corn; 2. *oats;* 3. peas; 4. clover.[21]

There are rusts attacking corn, peas, and clover. Also, fungous has been misspelled.

5. Lack of Scientific Definition. It is unnecessary here to go into detail with regard to the value of accurate definition other than to state that precise and clean-cut statements of the qualities which are characteristic of any phenomenon are requisite.

a. The characteristic that distinguishes mammals from other animals is:

1. The covering of hair
2. *The possession of milk glands.*

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[17]Sharpe, D. L., *The Spirit of the Hive*, Harper and Brothers, New York, 1925. Page 170.

[18]Oakes, M. E., and Powers, S. R., *Test of General Biology*, Form B, No. 83.

[19]Laidlaw, O. W., and Woody, C., *Michigan Botany Test*, Public School Publishing School, Bloomington, Ill., Test 2, No. 9.

[20]Pieper, C. J., and Beauchamp, W. L., *Tests on Everyday Problems in* Science, Scott, Foresman and Company, New York, 1927. Unit 7, Form A, No. 35.

[21]Giles, J. T., Thomas, S. M., and Schmidt, H. W., Test 14, No. 46. Form A.

3. The presence of four legs[22]

The hair of mammals may also be used to distinguish this group from all other animals since nowhere in this kingdom does hair, structurally similar to that of the mammals, occur. As R. W. Hegner, the distinguished zoologist writes:

> Mammals also possess a covering of hair at some time in their existence and are distinguished by this characteristic as certainly as birds are by their feathers.[23]

b. Poison ivy has three leaves—*true*, false.[24]

Poison ivy is defined as a plant with three leaflets which make up one leaf; not as a plant with three leaves.

c. Hardness of water is due to the presence of dissolved compounds of—1. iron and aluminum; 2. *calcium and magnesium;* 3. sodium and potassium; 4. oxygen and hydrogen; 5. nitrogen and sulphur.[25]

Hardness of water may be due to dissolved compounds of iron and aluminum as well as those of calcium and magnesium.

6. Errors of Tradition. These consist of a heterogeneous assortment of errors belonging to all the classes mentioned previously. These errors have secured almost universal currency in practically all textbooks of general science and biology. They have not been rectified in tests simply because they are so widespread that they have acquired some semblance of respectability and to correct them might be said to smack of *lèse majesté.* Nevertheless, it is here that the duty of test-makers to perform a remedial function makes itself most apparent.

a. A plant gets none of its food from the air—true, *false.*[26]

The confusion between food and materials for the manufacture of foods is one which has been sanctified by a long tradition. A plant secures materials for the manufacture of food from the air, whereas the food itself is synthesized from these materials through the process of photosynthesis. Thus, simple substances like water, carbon dioxide, and inorganic salts, which the plant cannot break down to secure energy as foods but which are used in photosynthesis

[22]Jordan, E. B., and Foran, T. G., *Catholic High School Test in Biology*, Catholic University, Washington, 1926, Form B, Test 2, No. 15.
[23]Hegner, R. W., *College Zoology*, Macmillan Company, N. Y., 1931, p. 602.
[24]King, T. S., Virginia Biology Test, University of Virginia, University, Va., 1928. Form A, Test 2, No. 16.
[25]Powers, S. R., *Powers' General Science Test*, Teachers College, Columbia University, New York, 1926, Form B, No. 38.
[26]Giles, J. T., Test and Study Exercises in General Science, Laidlaw Brothers, New York, 1928. Exercise 18, No. 2.

are properly termed raw materials for the manufacture of food.

b. Insects breathe by means of gills, bronchi, lungs, *tracheae*, alveoli.[27]

Insects cannot be said to breathe since breathing is a physiological process confined to those animals which possess lungs. Plants, also, cannot be said to breathe for the same reason in spite of numerous test items to the contrary. They respire rather than breathe.

c. Alcoholic fermentation is produced by mold, *yeast*, bacteria, germs, air.[28]

Alcoholic fermentation is not confined to the yeasts alone for bacteria, molds, and germs may act in different degrees as true alcoholic ferments.

To resort to the technical vocabulary of testing, we may say that those items considered in the previous sections of this study have suffered from a lack of validity. Let us stop for a moment to consider what this term implies. If we turn to the textbooks devoted to testing we discover that validity refers to the extent to which a test item measures whatever it purports to measure. Does a particular item (or test) succeed in measuring the subject matter it claims to measure or does it deal with extraneous or erroneous materials?

But this, in turn, brings in new problems for consideration. For example, on the basis of what particular subject matter are we to determine the validity of test items? Thus, a test item might succeed in measuring a certain fact appearing in a biology textbook which it was designed to measure. To that extent, it is a valid item. But let us suppose that the fact appearing in the textbook is inaccurate. Is the item still valid?

As a means of solving such problems, the writer found it necessary to divide the concept of validity into two subsidiary concepts; immediate validity and original validity. To explain their meaning, it will be necessary to be more specific. If the reader will turn to page 492, he will note that question 66 states that De Vries, after experiments with primroses, announced the mutation theory. The authors of this test claim that the item is valid in that it was selected, among other sources, from subject matter appearing

[27]Jordan, E. B., and Foran, T. G., Form A, Part 1, No. 19.
[28]Dvorak, A., General Science Scales, Form S-2, No. 17.

in certain high school textbooks in biology.[29] Providing these textbooks also state that De Vries experimented with primroses, the item is valid in that it measures what it purports to measure, i. e., the subject matter appearing in the immediate source from which it was derived. Therefore, it may be said to possess immediate validity.

It remains to be seen now whether or not it is valid as a measurement of the original source from which it was derived, in this instance, the statement of De Vries himself. On the basis of his statement we can determine whether or not the statement possesses original validity. Here is what he says:

> As a result of my quest, I brought over one hundred species into cultivation, but only one of these turned out to be what I wanted. . . . The plant in question was Oenothera Lamarckiana (the evening primrose).[30]

Consequently, we may say that regardless of the immediate validity of the item, it is not a truly valid measure in that it does not possess original validity.

In addition to validity we find in the literature of testing a term called objectivity. This has especial reference to the need of questions being put in such form that they will be neither ambiguous nor confusing to those being tested or to those scoring the tests. Other factors working against the accuracy of test items are poor spelling, typographical errors, faulty sentence structure, and others.

1. Ambiguity.

a. The hard substance of the teeth is called—dentine, *enamel*, root, neck, bones.[31]

While it is true that the enamel is relatively harder than the dentine, nevertheless, the dentine is quite hard. As the Encyclopedia Britannica states in the article on teeth:

> The enamel rests on the dentine of which *hard* yet elastic substance by far the greatest part of the tooth is composed.—(italics mine).[32]

b. The colored parts of the flower are—sepals, *petals*, pistils, stamens, corolla.[33]

If it be true that the petals are the colored parts of the flower, then the corolla must also be colored since it is nothing other than a collective term for the petals. More-

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[29]Oakes, M. E., and Powers, S. R., Teacher's Handbook, page 2.
[30]De Vries, H., *The Mutation Theory*, Open Court Publishing Company, Chicago, 1911. p. 217.
[31]Dvorak, A., General Science Scale, Form R-1, No. 22.
[32]Encyclopedia Britannica, Vol. 15, page 846.
[33]Dvorak, A., General Science Scale, Form R-1, No. 25.

over, all the other parts of the flower which have been mentioned are colored to a greater or lesser degree, the sepals occasionally exceeding the petals in coloration.

c. Hydrogen is often used in balloons because—1. it does not burn; 2. it is colorless; 3. it is buoyant; 4. *it is the lightest gas known;* 5. it is heavier than air.[34]

While it is true that hydrogen is the lightest gas known, its use in balloons depends not so much on that fact per se, as it does on the fact that it is so buoyant.

2. Spelling and Typographical Errors.

a. The vertebrate are parts of the—heart, muscles, *backbone*, teeth, toes.[35]

Possibly by puzzling it out, an individual being tested might gather that the author of this test meant to say vertebrae rather than vertebrate. However, this takes valuable time which must be subtracted from that spent in exploring the biological, as contrasted with the proof-reading abilities of the student.

b. Carbohydrate foods are of especial importabohydrates but in different proportions—*true*, false.[36]

c. The substances which the cells of the body secret to counteract the poisons produced by germs are called—1. *phagocytes;* 2. incubation; 3. antitoxins; 4. ptomaines; 5. preservatives.[37]

Credit should be awarded to antitoxins rather than to phagocytes. Also, secrete has been misspelled.

3. Lack of Difficulty in Test Items.

a. Do you breathe more rapidly or less rapidly after strenuous exercise than before—*more rapidly.*[38]

Whatever difficulty there may be in this item is due to the fact that the meaning of strenuous is not understood by student.

b. A bright, blue sky indicates—bad, *fair*, rainy, gloomy, stormy weather.[39]

c. Malaria is carried by the mosquito known as—1. Culex; 2. Stegomyia; 3. *Anopheles.*[40]

This item (question 14) gives away the answer to question 12 which precedes it. Question 12 reads: Malaria is carried by 1, cat; 2, fly; 3, dog; 4, mosquito.

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[34]Powers, S. R., *Powers General Science Test*, Form B, No. 78.
[35]Dvorak, A., *General Science Scale*, Form R-1, No. 44.
[36]Giles, J. T., Thomas, S. M., and Schmidt, H. W., Form A, Test 11, No. 6.
[37]Giles, J. T., Thomas, S. M., and Schmidt, H. W. Form A, Test 10, No. 9.
[38]Pieper, C. J., and Beauchamp, W. L., Unit 3, Form B, Factual Test, No. 25.
[39]Dvorak, A., General Science Scale, Form R-1, No. 1.
[40]Giles, J. T., Thomas, S. M., and Schmidt, H. W., Form A, Test 10, No. 14.

STATISTICS OF 16 TESTS

	Date	Total Ques.	Types[41] Ques.	Considered[42]	Errors[43]
Biology Tests					
1. Cooprider: Public School Pub. Co., Bloomington, Ill.	1924	94	1-3-4-6	94	15
2. Ruch-Cossman: World Book Co., Yonkers-on-Hudson, N. Y.	1924	224	1-2-4	224	0
3. Laidlaw and Woody	1925	70	1-2-5	70	9
4. Jordan and Foran	1926	218	1-2-4	218	13
5. King	1928	386	1-2-3-4	386	24
6. Oakes and Powers	1929	200	1-2-3-6	200	23
7. Blaisdell: World Book Co.	1929	1250	1-2-3-4-6	151	12
8. Presson	1930	460	1-2-4	460	34
General Science Tests					
1. Toops: School Science and Math., Vol. XXV, Nov. 1925	1919	50	5	50	6
2. Ruch-Popenoe: World Bk. Co.	1923	140	1-2-4	140	6
3. Dvorak	1924	180	1	180	38
4. Giles, Thomas, Schmidt	1924	1100	1-3	300	48
5. Giles	1928	1280	1-3	160	15
6. Powers	1926	200	1	200	25
7. Pieper and Beauchamp	1927	1635	1-4	420	41
8. Pittsburgh: Gr. 9A	1929	100	1-3-4-5	50	9

The errors which are present in these tests may be ascribed to two basic causes: the first is lack of information on the part of the test-maker or in the sources from which his materials have been derived; the second has its origin in oversimplification of test items due to what are believed to be the needs of good pedagogy.

With regard to the first, it seems all too evident that many of our test-makers possess an inadequate scientific background. Whether or not they argue that the fault really lies in erroneous sources from which they have derived their measures, i. e., textbooks in biology and general science, state and city courses of study, the opinion of teachers, etc., still they may not evade their share of responsibility. Those who construct our tests should not be weather-vanes responsive solely to the idiosyncracies to be found in their sources. They should endeavor to correct those errors which are inevitably present in even the best textbooks or courses of study.

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[41] 1—multiple-choice
2—selection or matching
3—true-false
4—completion
5—simple question
6—miscellaneous

[42] Wherever possible, all the items present in a test have been considered. However, this was found to be impracticable with those tests having over 1000 items. With regard to those tests in general science, only those sections pertaining to biology have been considered. As for the Blaisdell test in biology, only the beginning test in each series of topics has been considered.

[43] No attempt should be made to compare the tests on the basis of the number of errors present in each inasmuch as the errors are not comparable; some being of minor and some of major importance.

With regard to the second cause of error: oversimplification of test items in the interests of pedagogical needs, a better argument can be presented. Thus, one might condone the presence of false generalizations, so prevalent in these tests, by arguing that the mind of the student is so constituted by virtue of its immaturity that it can be fed only upon the pabulum of pre-digested generalizations, be these true or false. The writer cannot see it this way at all. If it is true that the mind of the student is inadequately developed, would it not be a more rational procedure to teach him less, but to make sure that what is taught is true rather than half-true? Surely it is a harmful practice to employ such half-truths in teaching whereby much that is of great significance is carefully shelved out of fear that the student will become confused and turn away from "science" in disgust. Authors of tests seem to have entered upon a policy of superficiality—not all, it is true, but a good many—as a means of making mastery of biology and general science easier and easier.[4] At the same time they ignore the fact that their policy of pedagogical expediency cannot fail to present a distinctly false and superficial picture of the science to the student.

But this is not the most serious consequence. Even more portentous is the fact that such oversimplification tends to make a course, taught in accordance with such principles, extremely uninteresting, particularly to the intelligent child. It tends to discourage further interest in the subject because it ignores the appeal of a problem; of difficulties which call for further study and mastery. Our test-makers, if they are to construct valid and useful tests which will exercise a constructive effect upon the class-room must bear in mind that secondary students of average intelligence have outgrown, to a very large extent, the need for the pre-digested and simplified subject matter of the elementary school. They need to bite into something more substantial.

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[4]While it is not usual to think of tests as affecting the teaching procedures of subjects they are designed to measure, it should be noted that there are an increasing number of state and city science syllabi which have been constructed, at least in part, on the basis of some of these achievement tests.

SHUNTS AND ATTENUATORS

BY R. R. RAMSEY,

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[Dr. Ramsey, Professor of Physics at Indiana University in charge of the advanced work in Electricity and the courses in Radio, is the author of two excellent Radio text books: *The Fundamentals of Radio* and *Experimental Radio*.—Ed.]

In electrical measurements it is customary to shunt the galvanometer if the current through the galvanometer gives a deflection which is too large. Any small resistance can be used as this shunt, which is placed across the terminals of the galvanometer.

Most of the older, moving needle galvanometers were provided with shunts which were marked, 1/9, 1/99 and 1/999. These markings meant that the resistance of the shunt was 1/9th, 1/99th or 1/999th of the resistance of the galvanometer. If one used the 1/9th shunt, since the galvanometer resistance was nine times that of the shunt, the current through the shunt was nine times that in the galvanometer. Thus the current was divided, as it were, into ten parts, nine of which went through the shunt and one part through the galvanometer. In other words, 1/10 of the total current flowed through the galvanometer when the 1/9 shunt was used. Or 1/100 or 1/1000 of the total current flowed through the galvanometer when the other two shunts were used.

From this the galvanometer shunt equation,

$$I_g = I\,S/(S+G),$$ can be obtained.

In this equation I_g is the current through the galvanometer in Fig. 1, I is the total current, S the resistance of the shunt, and G is the resistance of the galvanometer.

Thus if G is one ohm, S is 1/9 ohm. Then

$$I_g = I(1/9)/((1/9)+1) = I(1/9)/(10/9) = I(1/10).$$

If one tries to check these shunts by first passing the current through the gal-

FIGURE 1

Diagram of a shunted galvanometer. Unless the resistance R is very great the total current through the battery will change when the value of the shunt, S, is changed.

vanometer and getting a large deflection and then by placing the 1/9 shunt and getting a second deflection, it will be found that as a general thing the second deflection will be greater than one-tenth of the first deflection. This is due to the fact that the total currents, I, in the two cases are not the same.

In the first place, assuming a simple series circuit, the current is $I_1 = E/(R+G)$ where E is the E.M.F. of the battery and R is the resistance of the battery and other connections and apparatus in circuit outside the galvanometer.

When the galvanometer is shunted the current is

$$I_2 = E/(R+(SG/(S+G)\ ).$$

Unless the resistance R is very great in comparison to the galvanometer resistance there will be considerable change in the value of the current, I, in the two cases.

If R should be zero, or if a low resistance battery such as a dry cell is connected to a very high resistance galvanometer, then $I_1 = E/G$ and $I_2 = E/(\ (SG)/(S+G)\ )$. The resistance in this second case will be seen to be 1/10 of G, since the shunt is 1/9 of G.

Thus I_2 is ten times I_1, and the second deflection will be the same as the first deflection.

Another shunt which is often used is Ayrton and Mathers' universal shunt, as shown in Fig. 2.

This shunt can be made of an ordinary resistance box of given resistance, 1,000 ohms, say. With this shunt, I is the current when connection is made between a and e in Fig. 2. For 1/10 of the current, connection is made around 100 ohms, or between a and d. The points c and b are used for 1/100 and 1/1000 of the current. This shunt will be seen to have the same defects as the simple shunt men-

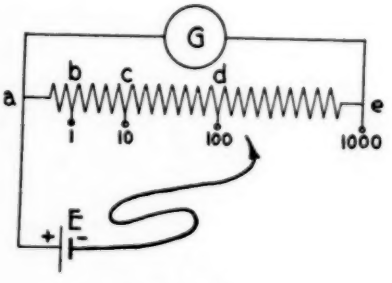


FIGURE 2

Ayrton and Mathers' universal shunt. This may be made of an ordinary resistance box with side plugs. The connections are made around 1/1, 1/10, 1/100, or 1/1000 part of the total resistance in the box. Unless the resistance in series with the battery is large the current through the battery will change with change of connection. This shunt is universal in that any galvanometer can be used.

tioned above in that unless precautions are used the total current I will change every time the shunt is changed.

In both of these shunts the current through the galvanometer is always 1/nth of the current through the battery at the instant the current is measured. But the battery current, I, will usually change with change of the connections.

The universal shunt is universal in that it can be used with any galvanometer. The proof of this is left to the reader. (Proof can be found in many text books.)

The trouble with both of these types of shunts is that the resistance into which the battery works, or the load on the battery changes when the shunt is changed. In order to keep the load of the battery constant it is necessary to insert an extra resistance between the battery and the shunt.

In telephone circuits, in order to prevent reflections it is necessary to keep the circuit balanced; i. e., the resistance of the load must be equal to the resistance of the source. In our illustration of battery and galvanometer we must assume that they have the same resistance. In order to keep the load on the battery constant we must insert resistance between the shunt and the battery, and in order to keep the resistance of the source to which the galvanometer is connected constant we must insert an equal resistance between the shunt and the galvanometer.

Then we have a connection as shown in Fig. 3.

The resistance marked Y is the shunt, and the resistances X are the inserted resistances. The combination of the X's and the Y is called an attenuator.

Since the battery and the galvanometer have the same resistance R, the circuit to which the battery is connected must have a resistance equal to R. Or the resistance of the circuit at a b, looking into the attenuator, must be R, and

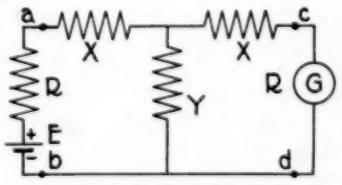


FIGURE 3

A circuit made of a battery and a galvanometer shunted with an attenuator. If the battery and galvanometer has the same resistance, R, and the attenuator has the same characteristic impedance, R, the current through the galvanometer will be 1/k of that through the battery. The current through the battery will be the same value independent of the value of k.

likewise the resistance of the circuit at cd, looking backwards into the attenuator towards the battery, must be R.

The resistance of the combination looking into either end is $X+(Y(X+R)/(X+Y+R)=R$. From this we get

$$Y=(R^2-X^2)/2X. \quad (1)$$

In terms of the equation of a shunted galvanometer. $I_g=IS/(S+G)$, we have $I_g=IY/(Y+X+R)$ or $Y+X+R=kY$ where $k=I/I_g$.

From this we get

$$Y=(X+R)/(k-1) \quad (2)$$

Combining equations (1) and (2) we get

$$X=R(k-1)/(k+1) \quad (3)$$

Substituting this value of X into equation (1) we get

$$Y=2Rk/(k^2-1). \quad (4)$$

Therefore, knowing R and k one can calculate the values of X and Y. Thus if R is 100 ohms and k is 10, we have

$$X=9/11 \text{ of } 100 \text{ or}$$
$$X=81.818 \text{ ohms},$$
$$\text{and } Y=200(10/99) \text{ or}$$
$$Y=20.202 \text{ ohms}.$$

This attenuator can be constructed of three ordinary resistance boxes, placing 81.8 ohms in two for the X's and use the third with 20.2 ohms for the Y.

Experimentally this can be tested by means of a galvanometer which is not too sensitive. Resistance can be inserted in series with the battery to make its resistance equal to the resistance of the galvanometer. Connecting together we get a deflection proportional to the current, I. Knowing R and k, X and Y can be calculated, and then connecting the attenuator into the circuit the deflection will be 1/kth of the first deflection, provided the deflections are proportional to the current.

The resistance R is known as the characteristic resistance. Usually in telephone work inductance and capacity, as well as resistance, enter into the constants of the line, since the current is alternating and we usually speak of the characteristic impedance, Z, instead of the characteristic resistance, R.

In Fig. 4, if we measure the resistance between a and b we have $50+75=125$ ohms. If we connect another section of an attenuator to the points c and d and measure, we get 102.2 ohms. If we connect three sections together and

measure, we have 100.24 ohms.

As the number of sections are increased the resistance becomes nearer and nearer to exactly 100 ohms. From this we get the following definition of characteristic impedance.

The characteristic impedance is the impedance of an infinite number of sections of the line.

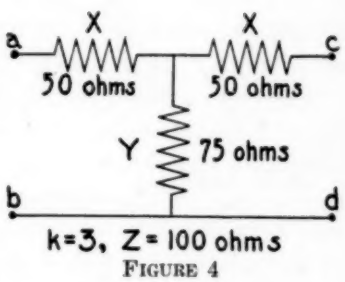


FIGURE 4

Diagram of an attenuator where k is 3 and the characteristic impedance, Z, is 100 ohms. The values of X and Y are those calculated from equations (3) and (4). The values in this case happens to be whole numbers. The impedance of three sections of this attenuator is nearly 100 ohms. The same will be true if the value where k equals 10 are used. The attenuation of this attenuator when k is 3 is 9.74 decibels.

If 100 ohms are connected to the points c and d the resistance of the combination measured at a and b is 100 ohms. And if 100 ohms are connected at a and b the resistance measured at c and d, the result is 100 ohms. The section of the attenuator is said to have a characteristic impedance of 100 ohms.

A second definition of characteristic impedance is given below:

Characteristic impedance of a line or of a section of a line is that impedance which if connected to a terminal of the line or to the terminal of a section of the line causes the line or section to have an impedance equal to the characteristic impedance.

It has become customary to speak of the attenuation produced by an attenuator in terms of decibels. The number of decibels is ten times the logarithm, base ten, of the ratio of the input power to the output power. Since power is I^2R the number of decibels is ten times the logarithm of the ratio of the square of the currents. Or the attenuation is given as 20 log I/I_g. If the current ratio, k, is 10, since Log 10=1, the attenuation is 20 decibels. If k is 100, the attenuation is 40 db.

For a table giving the attenuation for various values of k see "The Fundamentals of Radio," p. 336.

Commercial attenuators are on the market which are very convenient to use. These are arranged so that the attenuation can be made any desired amount simply by

changing switches or by rotating dials. The markings on the dials are given in decibels.

The characteristic impedance of these attenuators are fixed and are intended to be used in circuits of the same characteristic impedance. I think it well to stress this point. Too often attenuators are used without any regard to the characteristic impedance of the circuits.

The attenuator will produce attenuation but the amount of attenuation will not be the values read from the dials. It is possible to calculate the attenuation if you know the impedance of the various sections. To calculate one must know the theory.

In some circuits troublesome reflections may be produced by the unmatched impedances. In all probability it will save time and trouble if one will make up a simple attenuator of resistance boxes to use, unless the variable attenuator matches the circuit. One must remember that the impedance of the input and the impedance of the output must be the same and that the characteristic impedance of the attenuator must be this same value.

The most common illustration, perhaps, is the output circuit of a modern radio set. The impedance of the loud speaker and the impedance, plate resistance, of the tube, must be the same. Figure 5.

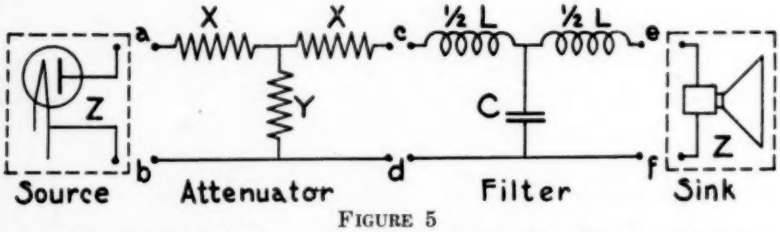


FIGURE 5

Showing a tube, a loud speaker, an attenuator, and a filter. If these all have the same characteristic impedance, Z, there will be no distortion when any or all are connected in the circuit.

If a volume control is used it should be an attenuator whose characteristic impedance is that of the circuit.

If these conditions are not met, distortion is produced in the output circuit. (If the impedance of the loud speaker and tube are different they may be matched by means of a transformer. "Fundamentals of Radio," p. 339.)

T pad volume controls are on the market which are made

of three simple rheostats. These can be constructed to work in any given circuit. The characteristic impedance of those which I have measured changes considerably with the setting of the dial, showing there has been fault in design or in the construction.

MICHAEL FARADAY, SEARCHER FOR TRUTH FOR ITS OWN SAKE

By Elliot R. Downing,
The University of Chicago

This has been called the "Age of Electricity." In many respects it is an apt designation. It is sharply demarked from preceding periods for while frictional electricity was known to the ancients it was merely a curiosity. Voltaic electricity and induced currents were discovered nearly simultaneously only a little over a hundred years ago. The laws that govern their action are yet more recent discoveries. Until these principles were known there was no possibility of the invention and improvement of all those electrical devices that depend in their action on these laws. It is these devices that have changed so greatly the complexion of our civilization—the telegraph and telephone, the arc and incandescent electric lights, and most important of all, the dynamo and motor. These latter have put at man's service a vast new power, making simple hitherto impossible tasks, relieving mankind of drudgery and so cheapening production that they have added enormously to man's wealth and comfort. These devices were created with amazing rapidity when once the underlying principles were known and they altered remarkably the appearance of civilized countries as well as the conduct of their affairs. The age of electricity was almost born mature.

The man whose discoveries made this transformation possible was Michael Faraday. He discovered induced electric currents and the laws of their action, he proved the identity of the several kinds of electricity, he devised the first simple dynamo and electric motor, he contributed greatly to the theoretical knowledge of electricity and magnetism, of light and sound and added much to our knowledge of chemistry as well as to its applications to industry. Tyndall calls him the world's greatest experimentalist in the field of physical science.

Faraday came from a humble family of tradesmen. His father and older brother were blacksmiths, his mother a farmer's daughter, his two sisters in no wise extraordinary. His father's brothers, six of them, were all employed at simple trades. The only remarkable thing about his family and his forbears is that for at least three generations they were devout members of the Sandemanian Church, an offshoot of the Presbyterians. Faraday was himself a member of this church for forty-six years, an elder and often the preacher. But English working families were for the most part Christian church goers. The Faradays, however, took their religion rather more seriously than usual so that it permeated all the work-a-day relations.

Michael Faraday was born at Newington, Surrey, Sept. 22, 1791. His birthplace was then in the country at the edge of London, but has since been swallowed up in the expanding metropolis. When Michael was five, the family moved to Jacob's Well Mew, in Charles St., Manchester Square, in London itself. While here Michael attended school and learned to read, write and cipher. He played out of school hours with the other lads on the streets and vacant lots.

At thirteen years of age (1804) he went to work as errand boy for a Mr. George Riebau, a stationer and bookbinder at No. 2 Blandford Street. He is described as a curly headed lad, with frank smiling face, who went whistling on his errands, always anxious to oblige the customers to whom he delivered papers, collecting them again when they had been read. The next year he was apprenticed to the same man for a period of seven years to learn his business. Not only did he learn to bind and sell books, but he read to good purpose such as came under his hand that dealt with chemistry and natural philosophy. It was Mrs. Marcet's Conversations in Chemistry that first opened up the delights of that subject to him and made him realize that it was not prohibitively difficult. In later years he came to know the author personally and for many years sent her copies of his papers when he published his chemical discoveries in scientific journals. The articles on electricity and magnetism in the Encyclopedia Britannica first woke his enthusiasm in that subject. He made himself a

frictional electrical machine and performed chemical and physical experiments evenings, such at least as could be done with an occasional penny's worth of supplies.

He must have been a rather remarkable lad, this apprentice, reading and experimenting in science and holding himself to a program of self improvement. Some of his early letters written during his apprenticeship have been preserved. They read like the letters of a well educated gentleman. Yet he must have acquired his command of language and style largely by his own efforts. He made friends with several men both young and old who were customers at the stationery store. Masquerier, a French artist, lived at Riebau's for a time and taught Faraday how to draw while Faraday in return dusted the artist's room and brushed his boots. He enlarged his circle of worthwhile acquaintances when in 1810 and 1811 he attended some lectures on natural philosophy given by a Mr. Tatum.

Another acquaintance made at the book shop, a Mr. Dance, changed the whole course of Faraday's life when he took him with him to four of Sir Humphrey Davy's lectures at the Royal Institution. Davy was at this time professor of chemistry and director of the laboratory at the Institution—a research foundation originally initiated by that erratic American who afterward became the French Count Rumford.

These lectures were delivered in the Spring of 1812. Faraday took copious notes, then wrote them up in full and bound them. He had now completed his apprenticeship and went to work as a journeyman book binder with a Mr. De la Roche. But commercial life seemed very sordid to him and the pursuit of science exceedingly attractive. Encouraged by Mr. Dance he wrote to Sir Humphrey Davy begging him to inform him if he knew of an opportunity whereby he could make a beginning in scientific pursuits. He sent him at the same time his notes on the four lectures he had attended. This was in December, 1812. Now it chanced that the following Spring the assistant at the Royal Institution, a Mr. Payne, left, and Davy offered Faraday the place. It was promptly accepted. He was to get out of the apparatus room such appliances as were needed by the lecturers, assist them during the lectures, clean up and

put away the apparatus, clean and dust generally, and assist in such other ways as might be required. He was to receive 25 shillings a week and have a room on the top floor of the Institution.

It was an opportunity for this twenty-two year old lad. Davy was one of the foremost chemists of his time. His brilliant lectures were attracting large and distinguished audiences to the Royal Institution. Faraday was neat, careful, and systematic, and his help was appreciated by Davy, who was only too willing to be relieved of the drudgery and orderliness essential in the conduct of chemical experimentation.

That same year Faraday joined the City Philosophical Society—a group of men who met regularly for discussion and self improvement. Each one in turn was required to prepare a lecture and present it to the group. This society had been founded by Tatum, whose lectures on natural philosophy had been an inspiration to Faraday. Some of the congenial young men whose acquaintance he made at these lectures were also meeting once a week in Faraday's room at the Institute to help each other in composition, grammar and oral expression. Their criticisms of each other were candid and severe but kindly and Faraday felt they were very profitable.

The fact that Faraday promptly made himself invaluable to Davy is evident from the fact that Davy offered to take him with him as amanuensis and assistant on a trip to Europe the Fall of 1813, only six months from the time he began his work at the Royal Institution. That trip lasted a year and a half. They travelled through France, Italy, Switzerland, Germany, stopping at the centers of chemical interest, met many of the great scientists—Ampere, Biot, Dumas, Gay-Lusse, Volta, and many others, and worked on a number of chemical problems at such places as afforded exceptional opportunities. Davy, who was a man of distinction and of large means, travelled in rather luxurious style, especially since his wife accompanied him. He was received with marked respect and accorded many privileges as a visiting scientist of repute. Faraday thus had remarkable opportunities and won many scientific friends both by his manifest ability and his charming personality.

Davy's English valet refused to accompany him and he could not secure one on the continent. So Faraday, out of the kindness of his heart, undertook to see to the luggage, arrange for hotel accommodations, and similar duties usually devolving on a servant. Mrs. Davy was haughty and inclined to treat him as a servant only. So the trip was not without its unpleasant features, though Davy himself was considerate. But there were compensations. They were in Rome during the Carnival and Faraday enjoyed it immensely, going to the masquerade in night gown and night cap, frolicking with the gay Italians, and catching their spirit of light hearted play.

But he was working hard too, studying to master the foreign languages, French, Italian and German, studying chemistry, and helping Davy in his numerous experiments. In Paris they worked on the newly discovered iodine; collected it from sea weeds on the shores of the Mediterranean in Southern France. They tried burning diamonds in an atmosphere of oxygen when in Florence they had the use of an exceptionally powerful burning glass belonging to the Grand Duke of Tuscany. They analyzed the escaping gases from the volcanic vents about Naples. On the whole the trip was to the observant and studious Faraday better than a university education.

On their return Faraday resumed his work at the Royal Institution. Shortly he himself was delivering lectures on chemistry before the City Philosophic Society. The same year, 1816, he published in the Quarterly Journal of Science his first paper, on the analysis of a sample of caustic lime. Other papers followed in rapid succession. He was not only assisting Davy in his research work, notably on the safety lamp, but was turning out much original work of his own. Six of his papers appeared in the Quarterly in 1817, eleven in 1818, and nineteen in 1819. He was rapidly becoming an expert chemist. His fees as a consultant in legal cases and industrial enterprises were increasing. In 1821 he was promoted from assistant to superintendent of the house and laboratory, his salary £100 a year.

This same year he was married to Sarah Barnard, whose father was a silversmith, a member of the Sandemanian congregation where Faraday attended church. Faraday was always a chivalrous lover, Mrs. Faraday a brilliant

and devoted wife. It was an event which in Faraday's mind "contributed more than any other to his earthly happiness and healthful state of mind." Liebig wrote to him in 1844, "With the purest pleasure I bring to mind my walk with her (Mrs. Faraday) . . . when I was afforded a glimpse of the richness of her mind. What a rare treasure you possess in her." He now had additional rooms at the Royal Institution and here he and his wife lived.

Faraday now was tireless in his experimentation. He liquified chlorine and other gases, spent months in work on alloys of steel with other metals, made many new sorts of glass trying to find one that would be an improvement on any then used for optical instruments, discovered benzine, but most significant of all in view of his later work he succeeded in making a wire carrying an electric current revolve about the pole of a bar magnet or if the wire were fixed the magnet revolve about it.

In 1824 he was elected a fellow of the Royal Society. In 1825 he was made Director of the Laboratory of the Royal Institution and began giving lectures there. In 1829 he was made lecturer at the Royal Academy at Woolwich at a salary of £200 a year.

The year 1831 was one of momentous decisions and begins the most brilliant period of his life. He decided to give up all commercial work in chemistry and devote himself entirely to research work. His fees in 1830 had amounted to over £1000 and were constantly increasing. To give this up when his total income from other sources was scarcely a third as much required courage. But Faraday delighted in research. Moreover, he had a profound sense of his obligations to the Royal Institution. It had fathered him scientifically and given him his training and his opportunity. He felt that to it he owed his best efforts. So that he might devote his whole energy to research he cut down his social duties, refused to dine out or give dinners, resigned from social and philanthropic organizations, and would see callers for a limited time only on three afternoons each week. He was at his laboratory early and late. It would seem almost as if he had a premonition of the great discoveries he was about to make that required his concentrated attention and effort.

Faraday had for many years kept a sort of journal—a commonplace book as he called it at first. Later it was "Chemical Notes, Hints, Suggestions, and Objects of Pursuits." Here were recorded ideas that occurred to him, suggestions in regard to experiments to be performed, etc. As early as 1822 there is entered as one thing to be done, "convert magnetism into electricity." He with Davy had repeated Oersted's and Ampere's experiments, in fact Faraday confirmed all the experiments that had been performed so that he could write from first hand knowledge when he published in the Annals of Philosophy his historical sketch of electromagnetism in 1821. He felt certain that if electricity could be converted into magnetism as in the electromagnet, that magnetism could be made to produce electricity. But how! In 1824 and 1825 he tried many experiments. He wound insulated copper wire about a magnet but no current appeared in the wire. He ran a current through a coiled wire which of course became a magnet then coiled a second wire about the first but no current appeared in the second wire.

Now in the summer of 1831 he returns to this problem, still convinced in spite of all his failures that there must be some way to convert magnetism into electricity. He wound on the right hand side of a ring of soft iron many turns of insulated wire and connected the ends to a battery. On the left hand side were wound many turns of similar wire the ends of which were connected to his galvanometer. But increase the strength of the current flowing through the right hand coil as much as he could, still no current appears in the left hand coil. But now he does note a hitherto unobserved phenomenon.

At the moment when the current is turned on there is a slight swing in the needle of the galvanometer and when the current is turned off a similar swing but in the opposite direction. He repeats this many times. Then he sees the significance of the results. It is not the steadily flowing current that induces the current in the parallel wire but the change of state in the wire when the current is turned off or on. The change not the flow is the important thing. Now he hurries to repeat another experiment that had previously failed. An insulated wire is wound about a

short cylinder of soft iron. Its ends are attached to the galvanometer. The pole of a bar magnet is applied to one end and the opposite pole of a second bar magnet is rapidly brought near the other end. As it approaches, the galvanometer needle swings, as it is withdrawn the needle swings again in the opposite direction. Now he believes he sees the reason why an earlier experiment had failed. He had wound many turns of insulated wire about a bar magnet but no current had appeared in the wire for the magnet was at rest. Suppose now he introduced changes and moved the bar magnet into and out of the coil. What would happen? He tried it and saw the needle of the galvanometer swing to one side as the magnet entered the coil and reverse the direction of its swing as the magnet was withdrawn. Again he had succeeded in inducing an electric current by magnetism. Now he winds two insulated wires parallel to each other turn by turn about a pasteboard cylinder. The ends of one are connected to the battery, the ends of the other to the galvanometer. At the moment the current is turned on in one wire an induced current is noted in the second wire running in a direction opposite to the inducing current and when the inducing current is broken the induced current is again manifest but going in the same direction as the inducing current. Then he discovers that the mere approach of a wire to a second one through which a current was passing induced a current in the first wire, opposite in direction to the inducing current; its withdrawal produced a current running in the same direction as the inducing current.

These discoveries were made from the middle of August until mid-October. Now he writes up his results and presents them in a paper read to the Royal Society, November 24, 1831.

After a brief rest he comes back to his laboratory to make a variety of simple electric machines. One consists of a copper disc, some twelve inches in diameter, mounted on an axle so its edge can rotate between the opposite poles of a powerful magnet. One wire from the galvanometer was in contact with the axle, the other was held in contact with the edge of the disc. When the disc was rotated a current of electricity was sent through the wire, its direction depending on the direction of rotation of the disc. It

continued to pass as long as the disc was rotated. He foresees how machines of this sort will be a source of mighty power but he is not inclined to perfect them for such a purpose because he prefers "discovering new facts and relations dependent on magnetic and electric conduction."

Faraday was subject to spells of illness when he became very dizzy and often he suffered temporary loss of memory. He was forced to rest between his periods of intense application at the laboratory. Between 1839 and 1844 he was ill much of the time and went away for a rest in Switzerland.

He had been working very hard. Not only conducting his experimental investigations but lecturing often at the Royal Institution and at the Royal Academy at Woolwich. In 1836 he had been appointed advisor to the Board of Control of British Lighthouses and had devoted much time to its affairs. The compensation was £200 a year. The same year he was granted a pension of £300 annually in recognition of his masterly research work.

In 1844 he is sufficiently well to return to his research with vigor. This time it is to attack the relation of magnetism to light, and he shows that the plane of polarization is subject to rotation by the force of magnetism.

But to describe or even list Faraday's discoveries and his contributions to the theories that underlie the physical sciences would require volumes not pages. Such terms as electrode, electrolytes, electrolysis, anode, cathode, anion, cation, ion, were all introduced by him. He showed that the amount of chemical work performed by a current, as in electrolysis, is in proportion to the amount of electricity used, that the component substances appear during electrolysis of a compound (as water) in proportion to their atomic weights. He almost stated the law of the conservation of energy two years before Mayer, "In no case is there a pure creation or production of power without a corresponding exhaustion of something to supply it." "Powers are expended in the same proportion as the effects are produced."

He was honored with membership in more than twenty foreign scientific societies. He was offered the presidency of the Royal Society and of the Royal Institution both of

which he declined, feeling that the mental strain would be too great.

One marvels at the fecundity of Faraday's mind, the fertility of hypothesis, the tenacity with which he held on year after year to problems until they were solved, the scope of his interests, contributing as he did valuable research to so many lines both in chemistry and physics. But one admires quite as much the simplicity and beauty of his Christian manhood.

The intensity of his application to his investigations, to his lectures, to his service on various Boards and to his duties as a citizen brought on with increasing frequency as he grew older his old giddiness and loss of memory. He had to give up experimentation for he now would forget before he was through for what purpose the experiment was started, nor could he remember the results long enough to write them down in his notebook. Through the graciousness of the Queen he was provided with a delightful house in 1858 on Hampton Court Green and here he passed his remaining days, suffering with fortitude, always cheerful in his certain faith, comforted by his many friends, cared for and upheld by his devoted wife. He died August 26, 1867, at the age of 76. He was a dutiful son, a devoted lover and husband, a citizen who gave freely of time and money to help his fellows, a superb scientist, a fiery champion of righteousness, a humble Christian gentleman.

FEW LOW GRADES AT SYRACUSE

Of the 1654 freshmen admitted to Syracuse University, one of the largest classes ever admitted, the percentage of those who are back in their work, or "below grade," at the middle of the year is the lowest on record. For the first time since fraternity averages have been compiled, the scholarship of the fraternity man shows a vast improvement. This, in the opinion of the Registrar, is due to the compiling and publishing of fraternity records over a period of years and the building up of competition between the fraternities in the field of scholarship. Of the 1600 freshmen, only 151 were admitted with any "conditions," and approximately 40 per cent held a scholarship rank in the upper quarter of their high school classes. The number of students transferred to Syracuse from other colleges and universities was 326 men and women, doubling the highest previous record. All of these transfers were in good standing in the institutions which they left.

KEM—AN INSTRUCTIVE CHEMISTRY CARD GAME

By Dorothy Brown,

Nottingham High School, Syracuse, N. Y.

As a rule, one doesn't expect to get much pleasure from a visit to the doctor's office. However, as with all good rules there are exceptions—which proved to be the case with me. Complying with the school requirement to be vaccinated, I be-took myself to the doctor's office. As I was about to leave, the doctor picked up my Chemistry book with the remark "So you are taking Chemistry in school?" He continued, "Chemistry is my hobby." The conversation developed in his showing me an absorbing Chemistry card game which he had evolved. This game has proved to be intensly interesting as well as instructive to the students in Nottingham. We have changed it slightly and enlarged upon it somewhat. Now we are passing it on to other devotees of Chemistry and we hope it will prove to be as interesting a game in your Chemistry class as it has in the Chemistry class of Nottingham High School.

The game—KEM—is played similar to Flinch. The most convenient cards for use in Kem are 7.5 cm. by 12.5 cm. At the top of the card is printed the symbol of the element

Na Sodium (+)	
	SALTS
NaCl	Sodium Chloride Salt Common Salt
Na_2CO_3	Sodium Carbonate Soda Washing Soda
$NaHCO_3$	Sodium Bi-Carbonate Bi-Carbonate of Soda Baking Soda
NaOH	Sodium Hydroxid Soda Lye
Na_2SO_4	Sodium Sulfate Glauber's Salt
$NaNO_3$	Sodium Nitrate Saltpeter

Fig. 1

Cl Chlorine (−)	
	SALTS
NaCl	Sodium Chloride
KCl	Potassium Chloride
$CaCl_2$	Calcium Chloride
NH_4Cl	Ammonium Chloride
$ZnCl_2$	Zinc Chloride
AgCl	Silver Chloride
$AuCl_3$	Gold Chloride
	ACID
HCl	Hydrochloric acid Muratic acid Hydrogen Chloride

Fig. 2

or a group. Below it is the chemical name and in the right hand corner is the valence, as Na—Sodium—(+), in Fig. 1.

The middle half of the card contains the formulas, chemical names and trade names of all the salts (of Sodium) to be used in the game.

In Fig. 2, the element is Chlorine, so the symbol, Cl, is at the top of the card and below it is the name—Chlorine. The valence is in the upper right hand corner—(-) minus one.

In the middle half of this card are the salts of Chlorine which are to be used.

In the lower portion of the card is the name of the acid to be used.

The Carbonate group would have the CO_3 group at the top and the name—Carbonate—below it. The valence will be shown by two minuses in the upper right hand corner.

The middle portion would have the salts of carbonic acid as:

	Salts
Na_2CO_3	Sodium Carbonate
	Soda Ash
K_2CO_3	Potassium Carbonate
	Pearl Ash
$(NH_4)_2CO_3$	Ammonium Carbonate
$CaCO_3$	Calcium Carbonate
	Marble
$ZnCO_3$	Zinc Carbonate
	Zinc White
$PbCO_3$	Lead Carbonate
	White lead

The lower part of the card would have the acid as:

	Acid
H_2CO_3	Carbonic Acid

The Ammonium card would be made in the same manner with NH_4 at the top and below it the name—Ammonium—with a single plus valence in the upper right hand corner.

The middle section would have the names of the ammonium salts, but the lower part would have:

	Hydroxide
NH_4OH	Ammonium Hydroxide

As one hundred cards are desired it is easier to select the salts which you wish to use and then make acid radical groups and elements from these.

Directions For Playing

The cards are counted out into packs of 5 and then piled crosswise as you would stack Flinch cards. Each player takes from the stack one of the piles of 5 cards which is his hand. Then each player takes two piles of 5 cards each from the stack in the center which is his Kem stack (Just as in Flinch—this stack of 10 cards is called a Flinch stack). The cards of the Kem stack are placed at the right of the player with the written side upward. The idea of the game is to match 2 or more of the elements or groups found at the top of the cards to form some compound listed on the card.

Plays are made by matching 2 or more cards from the hand or by using the top card of your Kem pack to form some compound which is then laid on the table in front of the player. There should be at least two Na and one CO_3 card to form the compound Na_2CO_3. In like manner, one Na one H and one CO_3 card would be needed to form $NaHCO_3$. The player names the compound as he lays it down. Always play from the Kem stack when it is possible. If the player names the compound wrong or plays from his hand when he can play from his Kem stack, he is "Kemed" by any of the other players. For this offense he is punished by losing his play and he must lay down a card in front of himself. This card may be used by any of the other players to make compounds. He also receives a card from the bottom of each of the other player's Kem stack, these cards being placed at the bottom of his Kem stack.

The play now passes to the player on the left who plays until his Kem stack is gone, or until he is "Kemed" by one of the other players, or until he can no longer make compounds with the cards which he holds. When a player is thru playing for any of these reasons, he lays down a card in front of him as a signal for the next player to begin. This card can be used by any of the other players to make compounds and if it is not used when possible, the person failing to use it is "Kemed." When the cards of the hand are exhausted, pick up another of 5 from the reserve stack and continue playing.

The one who plays his Kem stack out first is the winner and is given credit according to the valences as designated in the right hand corner of all cards which have not been made to form compounds of the other players.

A COMPARATIVE STUDY OF SCIENCE EDUCATION IN SWEDEN AND THE UNITED STATES

By H. F. Kilander,

Upsala College, East Orange, N. J.

In recent years much discussion has centered around the science education of our schools. Considering the varied programs of science instruction in our country, it is evident that there exists a great diversity of opinion and practice in this field. Numerous investigations have been undertaken to help solve many of the problems. The writer recently made an extended study of the science program of Sweden. In the following discussion a comparative picture of the science education in Sweden and the United States is presented.

Sweden has long been known for its interest in the scientific field. In proportion to its population that country has produced an exceptionally large number of scientists, naturalists, and explorers. Among the more prominent individuals may be mentioned Linneaus, Arrhenius, Scheele, Dahlen, Berzelius, Nobel, Montelius, Nansen, and Nordenskold. Sweden has a population of six million, and compares in size with that of our larger states. Its educational systems and practices are in many respects similar to those of Germany. A brief survey of the educational organization of Sweden will first be given.

Education stands on a high plane in Sweden. A minimum of seven years of schooling is required of all children. The chief difference in education between Sweden and the United States is that the latter country has universal secondary education. In order to provide suitable training for all types of students, Sweden offers carefully organized groups of curricula suited expressly to the various types of ability. Largely as a result of this educational philosophy, in Sweden, as in many other European countries, a variety of school types has developed, many of them paralleling each other in age of students and partly in scope of work. All courses above the lower elementary school constitute separate schools, each intended to meet a specific group of students and prepare them for definite life occupations.

Differentiation is as follows: First, a common schooling for all up to the age of sixteen in the elementary school and in other schools founded upon the elementary school, ex-

cept for those who enter the following types of schools. Second, the *real* school for pupils of good ability from ages 11 to 16; following this come various technical and trade schools. Third, the *gymnasium* for students of superior ability from ages 15 to 19; it prepares for the university and other higher schools. Compared with the American stu-

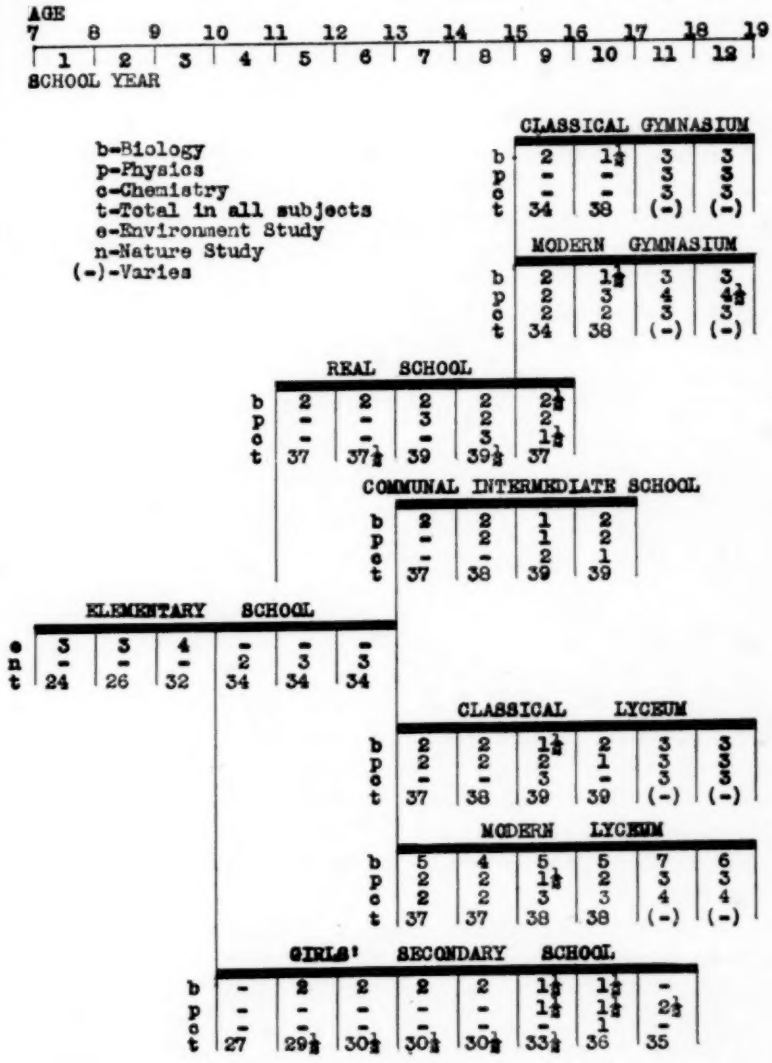

AGE
7 8 9 10 11 12 13 14 15 16 17 18 19
1 2 3 4 5 6 7 8 9 10 11 12
SCHOOL YEAR
b-Biology
p-Physics
c-Chemistry
t-Total in all subjects
e-Environment Study
n-Nature Study
(-)-Varies
CLASSICAL GYMNASIUM
b 2 1½ 3 3
p - - 3 3
c - - 3 3
t 34 38 (-) (-)
MODERN GYMNASIUM
b 2 1½ 3 3
p 2 3 4 4½
c 2 2 3 3
t 34 38 (-) (-)
REAL SCHOOL
b 2 2 2 2 2½
p - - 3 2 2
c - - - 3 1½
t 37 37½ 39 39½ 37
COMMUNAL INTERMEDIATE SCHOOL
b 2 2 1 2
p - 2 1 2
c - - 2 1
t 37 38 39 39
ELEMENTARY SCHOOL
e 3 3 4 - - -
n - - - 2 3 3
t 24 26 32 34 34 34
CLASSICAL LYCEUM
b 2 2 1½ 2 3 3
p 2 2 2 1 3 3
c - - 3 - 3 3
t 37 38 39 39 (-) (-)
MODERN LYCEUM
b 5 4 5 5 7 6
p 2 2 1½ 2 3 3
c 2 2 3 3 4 4
t 37 37 38 38 (-) (-)
GIRLS' SECONDARY SCHOOL
b - 2 2 2 2 1½ 1½ -
p - - - - - 1½ 1½ 2½
c - - - - - - 1 -
t 27 29½ 30½ 30½ 30½ 33½ 36 35

DIAGRAM 1

A Comparative Chart of the Science Curricula of the Swedish Elementary and Secondary Schools.

dent who has finished the fourteen years through the junior college, the *gymnasium* graduate with his twelve or thirteen years of training is more mature and capable of continuing university or professional work. Fourth, the private girls' school which builds upon three years of elementary school and is itself eight years in length. See Diagram 1 for this relationship of schools and ages of the students. Having once selected a given school form, a student continues with its fixed curriculum since the curriculum of each school type is prescribed for all except in the last two years of the *lyceum* and the *gymnasium*.

School authorities concern themselves with a definite statement of the aims of each course, a definite sequence and relatedness in the content of subjects and curricula, competent teachers, and a determination of results by final examinations at the end of the school course. All of these factors help to give the science instruction (as well as most other instruction) a different picture from that common in the United States.

The sciences occupy a place of much greater importance in the schools of Sweden than in the corresponding schools of America. In fact, the amount of science in terms of year-hours taught in the state secondary schools is greater than for any other country. The science training begins as early as the fourth year of school at an average age of ten. Diagram 1 shows, in summary form, the number of year-hours of each science taught in each class of the elementary school and the various secondary schools. It is apparent that all schools—public and private, higher and lower, boys' and girls', have an extensive science program. Considering it as a whole, the amount of science which each and every student must study, regardless of school types, is rather high compared with the amount that the average American student studies during a corresponding period of years or classes.

Of the intermediate schools, the *real* school requires the most science because it serves as a foundation for the *gymnasium*. The communal intermediate school, which does not need to prepare so specifically for continued studies has the least, yet even this is not negligible compared with American schools. The higher secondary schools—the *gymnasium*, the *lyceum*—and the upper classes of the girls' school

give an increasing number of hours to science. In the eight years of the modern or scientific course—the fifth to and including the twelfth year of schooling—the total number of year-hours studied by all students is: biology, 11.5; physics, 10; chemistry, 7; and further elective hours respectively of 6, 8.5, and 6, in the last two years. Even in the classical course is the amount high. It should be recalled that these schools furnish the training necessary for entrance into the professional schools.

In contrast to the American secondary schools, the Swedish secondary schools actually bring the student to the place where he is ready to enter directly upon his professional training in medicine, dentistry, engineering, or the department of mathematics and sciences at the university. The training which in the United States requires the junior and senior high school and two to four years of college work as a preparation for professional studies, is obtained in Sweden in the *real* school and the *gymnasium*, these schools completing the first twelve to thirteen years of schooling.

The need for specialization does not entirely explain the large amount of science offered in most of the school types. Undoubtedly the fundamental reason is to be found in the recognition and belief that science training is a necessary part of the education of all people—that it is a valuable contribution and preparation for life. Some Swedish educators contend that the sciences are just as humanistic in their scope as are the traditional subjects and therefore should be included in the training of all students. It is recognized that there are both practical and cultural elements in science and that the sciences may be taught in such ways that each of these values may be obtained.

There is uniformity between different school types in the relative amount of time devoted to each of the various sciences. Most attention is given by all schools to biology. It is the oldest of the sciences, is less theoretical and mathematical, and therefore can be placed in the earlier years. It continues to be taught through the rest of the years as well because it is considered to have the most cultural and, at the same time, the most practical value.

Physics has been taught almost as many hours as biology by the end of the school course in most of the school types. Its extent and time of occurrence in a curriculum are deter-

mined mainly by the mathematical training of the student. Chemistry is deemed of least importance. Such is the opinion of many educators, and it is evident of course from the amount of time given to it; still there is a certain minimum of chemistry content which is considered desirable and which all students study. Its instruction is begun the latest.

The emphasis in each of the three major sciences is in general similar to that in the United States; yet there are a number of important differences as well. Biology still contains much of the old type of botany and zoology instruction, though there is a rapid trend toward making the subject more physiological and practical. Some educators urge that there be a greater stress on the economic side. This is where biology and geography have a common field. In practice the latter subject is closely bound up with biology instruction in all schools. Health education occupies an increasingly important position in the biology course wherein most of its instruction is given. Only in some of the higher elementary schools is hygiene taught as a separate subject.

The emphasis in physics is largely on the theoretical and the mathematical. From the American viewpoint, the stress on the latter is too great, especially when one considers the many other phases that probably would be more worth while to the majority of students, since only a few will continue their studies after graduation.

Chemistry comes nearest to being taught as it is in the United States. This is possibly due to the fact that it is the newest of the three sciences and therefore has less of the traditional dead material with which to contend.

Individual laboratory work is very limited in all sciences. The School Reform of 1927 increased the amount and made it compulsory. The crowded curriculum does not permit it to be taught to the extent that it is in the American schools. Demonstration experiments are very numerous and offset the lack of individual laboratory work.

The science training is influenced and determined to a very large degree by the definite and orderly sequence with which the subjects follow in the curriculum of each school type, and the sequence which is followed in each subject in respect to its own content. Examples in the science field are many. Biology instruction correlates with the instruction in geography in most years. Biology is begun earliest

because it needs less assistance from other subjects than the other two sciences. The physiology of digestion and of plants, however, must wait until the necessary chemistry has been studied. Physics is carefully graded so that the student can profit from his mathematical training. Phases of optics as a part of physics are deferred until geometry has made the student familiar with the properties of triangles. That which does not need mathematics is taught earliest. As chemistry depends upon physical phenomena and not vice versa, it is necessary to teach physics first, except in the case of ionization which is needed for an understanding of electrolysis. This principle of sequence and continuity is a very important and noteworthy feature of the educational program of the Swedish schools.

The curriculum considered as a unit is an essential point in Swedish education. Individual subjects are a part of it and contribute to it when and where they can. The American high school presents a different picture with its long list of subjects which may be chosen and studied by the year or the half year. Let it be emphasized that in drawing comparisons between the Swedish and the American school systems and practices, it must be kept in mind that features which are applicable to a fixed curriculum, as in Sweden, are not necessarily workable in the American school with its system of electives and its student bodies representing a wide range of intelligence and ability.

In addition to the carefully patterned curriculum, another feature binds certain parts of the teaching still more closely. Instruction in mathematics and physics is usually given by the same person; biology is taught by the teacher of either geography or chemistry; less frequently the chemistry teacher also instructs in physics. Furthermore, a teacher follows the same group of students through two or more years in the same subject. There may be several teachers in the school who are teaching the same subject-combination but to other parallel divisions of the same classes.

The teacher is the most important factor in acquiring an education. He is the first and most important source of the student's knowledge. He presents much new material which the student has not as yet read in his text, or which is not even contained in it. The teacher does not lecture to the

class but instead, by continuous questioning of a type which leads the student to think, guides the thoughts of the students in the development of new concepts. This method demands absolute attention, for mind-wandering is not tolerated. Classroom demonstrations introduce, supplement, and elucidate the discussions of the hour. Each period gives the pupil some new experiments which help to explain the textbook assignment of the day. Most of the hour is spent, however, in preparing the student for the advance assignment by means of demonstration experiments on entirely new subject matter. He is introduced to new ideas, facts, theories, and laws by means of experiments—not by the information available in the textbook.

The textbooks are condensed, factual, and well illustrated, and contain the essentials of the course. They do not lend themselves very readily to topic recitations; there is not sufficient substance to build upon. It is the duty of the teacher to supply the latter. The textbook is a secondary factor in instruction in Sweden.

It has been intimated that the experiments are largely in the form of classroom demonstrations. This method is considered more economical in both time and money, and certain features of the instruction are better adapted to it—the students see the experiment performed correctly, more rapidly, and with more correlation with the topic under discussion.

Individual laboratory study is designed to meet a different aim in the instruction, that of self-activity. This is stressed as one of the important aims of science instruction. The trend is toward more of this type of training in connection with the school work in general, and with that of science and shop work in particular, especially in the lower classes.

A new feature in the science training of the normal school is the combination of physics with sloyd. To have the pupils with the assistance of the teacher make much of the equipment is a means of meeting certain of the aims of education such as the self-activity principle, instilling interest, developing the practical side of the pupils, and making it easier for them to comprehend the physics work. Where the schools are handicapped by insufficient physics equipment, much of the apparatus can now be made, following printed instructions, at a nominal cost and a minimum of experience

on the part of the teacher. It is of special value in the rural schools from that point of view. This combination of physics and sloyd is one of the best educational practices in science teaching which Sweden has developed. The teachers so trained are introducing it into the early instruction in physics in the elementary and intermediate schools.

The training required of teachers in the secondary schools of Sweden is rather extensive. Their training beyond the secondary school level ranges from a minimum of three to four years for the *magister* degree to eight or nine years for those who take the doctor's degree. The work of these years is largely concentrated into two or three subjects which are later the ones to which the teacher must limit his instruction —quite different from the American practice. The university training is almost entirely academic and very extensive in the student's special fields. This training greatly exceeds in total time and for a given subject that required for entrance into the teaching corps of American high schools. This is especially true in the sciences. Very few professional subjects are studied, Swedish educators contending that subject-matter knowledge is most essential. A year of practice teaching under selected teachers and two years of regular teaching are additional requirements for permanent appointment to the state secondary schools. The state normal schools for elementary school teachers give a science training which, in terms of American high school subjects, is approximately equal to two years each of the three major sciences.

In the United States it is a general criticism of our education that the teachers are often poorly and inadequately prepared to teach. If American education is to equal that of Sweden, particularly from the point of view of instruction, higher standards must be set for teachers in the academic as well as in the professional training.

SUMMARY

1. The amount of science which every Swedish student must study is rather extensive compared with that of the average American student. Chemistry is least emphasized.

2. Science education begins earlier in the Swedish schools.

3. Each science, as a rule, is taught yearly so that a student is studying all three sciences simultaneously from one

to three hours weekly through almost the entire school time.

4. There is a definite sequence in the science training. This is possible because there are no elective subjects within a given school type.

5. The Swedish state secondary school prepares the student for direct entrance into the professional schools as well as the university.

6. Individual laboratory is very limited. Demonstration experiments occupy much of the class period and offset the lack of the former type.

7. Few examinations are given except at the end of the last year of a school form. These latter exercise a marked influence on the character of the school work.

8. The instruction centers about the teacher and the classroom demonstrations rather than about the textbook.

9. The university training of the secondary school teacher is almost entirely academic and very extensive in his two or three fields. His teaching subjects are limited to this group.

JUNIOR HIGH SCHOOL MATHEMATICS

Considerable attention is paid to courses in mathematics in Cleveland junior high Schools in the annual report of the Superintendent of Schools of that city, recently published by the Board of Education. The report, which is entitled "The Junior High Schools" and which embraces all departments of these schools, says relative to mathematics:

Junior high mathematics courses are planned with the idea of offering suitable material for those children who will leave school at the end of the junior high school, and those who will go on to senior high school. The need for some vocational training is met in two ways: by units of work throughout the course, which can be applied to later vocational uses, and by special classes with emphasis on the vocational aspects of work for pupils who must leave school early.

Besides making provision for special interests and abilities of pupils, the course of study in mathematics is planned to build a background of mathematical concepts necessary for the general reading of intelligent citizens, and to give the pupil a glimpse ahead at the possibilities which higher mathematics offers for the solution of real problems.

How Cleveland meets these two problems is described in further details in the report. Work of a curriculum committee in revising the course of study is reported upon.

"The Junior High Schools" may be obtained from the Division of Publications, Cleveland Board of Education, for $1.25.

ANNUAL MEETING

Eastern Association of Physics Teachers

One Hundred Twentieth Meeting

JEFFERSON PHYSICAL LABORATORY

Harvard University

SATURDAY, MARCH 12, 1932

PROGRAM

9:15 Meeting of the Executive Committee.

9:30 Business Meeting.
- Annual Report of the Secretary.
- Annual Report of the Treasurer.
- Report of the Nominating Committee.
- Election of Officers.
- Election of New Members.
- Reports of Committees.

10:00 Annual Address of the Vice-President, Mr. Lawrence A. Howard, High School, East Boston, Mass.

10:30 Address: "The Teaching of Science in European Secondary Schools." Prof. N. Henry Black, Harvard University.

11:15 Address by Prof. Franzo H. Crawford, Harvard University. "Some Recent Advances Made in Physics During the Last Ten Years."
- (a) Revision of the Bohr-Rutherford Atom
- (b) Wave Properties of Electrons
- (c) Corpuscular Properties of Light (Compton Effect)
- (d) Raman Effect

12:00 Illustrated Lecture in Cruft Laboratory covering certain other recent advances in Physics. By Mr. F. V. Hunt, Instructor in Harvard University.
- (a) New Electronic Devices and their Uses
- (b) Recent Researches in Architectural Acoustics
- (c) Supersonic Experiments with Demonstrations

2:00 Luncheon at the Dunster House on Memorial Drive.

3:00 Demonstration and Description of Some Interesting Apparatus Seen in Foreign Schools, by Prof. N. Henry Black, Harvard University.

4:00 Opportunity will be furnished for the members to inspect some of the interesting features of the New Research Laboratory, such as
- (a) The 100,000 volt Storage Battery.
- (b) Prof. Lyman's Ultra-violet Vacuum Spectrograph.
- (c) Prof. Duane's X-ray Spectrograph.
- (d) Prof. Bridgman's High Pressure Apparatus.
- (e) Other Researches in Progress.

OFFICERS FOR 1932-1933

President, Louis A. Wendelstein, High School, Everett, Mass.

Vice-President, Hollis D. Hatch, English High School, Boston, Mass.

Secretary, William W. Obear, High School, Somerville, Mass.

Treasurer, William F. Rice, Jamaica Plain High School, Boston, Mass.

ANNUAL REPORT OF THE SECRETARY

Our regular three meetings of the year have been held May 23, 1931, at Phillips Academy, Andover, Mass.; Dec. 12, 1931, at the High School, Somerville, Mass.; and March 12, 1932, at Jefferson Laboratory, Harvard University.

The programs have been varied and have presented the practical, the theoretical, and the educational side of the subject of Physics. The meetings have been unusually well attended.

Including those elected today the membership total is 187, consisting of 123 active members; 62 associate members; and 2 honorary members. This is 10 more than one year ago and is an increase of 12 active and a decrease of 2 associate members.

Three years ago 37% of the members were from outside Greater Boston and today about 45% are from outside Greater Boston. This increase may not be large enough to have much significance but it is at least indicative of an extension of our field of influence and suggests the desirability of making an effort to increase our membership in other sections of New England.

Respectfully submitted,
W. W. OBEAR, Secretary.

REPORT OF THE TREASURER, 1931-1932

Balance from 1930-1931		$271.61
Receipts:		
Dues, Active, 1930-31	$ 6.50	
Active, 1931-32	313.00	
Associate 1930-31	8.50	
Associate 1931-32	116.00	
Interest	10.20	454.20
		$725.81
Expenditures:		
Printing and Stationery	$ 27.44	
Expense of meetings	12.75	
Postage	19.70	
Clerical Work	22.50	
Salary of Secretary	50.00	
Committees	2.50	
	$134.89	
School Science and Mathematics	281.05	415.94
Balance		$309.87
Balance, March, 1932		309.87
Balance, March, 1931		271.61
Gain for year		$ 38.26
Assets:		
First National Bank of Boston, checking account		$ 51.27
First National Bank of Boston, savings account		255.60
Cash		3.00
		$309.87

Respectfully submitted,
WILLIAM F. RICE, Treasurer.

Examined and found correct March 3, 1932.
FRANCIS E. MASON, Auditor.

1930-31	Deficit	$ 78.37
1929-30	Deficit	129.09
1928-29	Deficit	16.27

1927-28 Deficit	5.23
1926-27 Gain	76.79

The nominating committee, Mr. Homer LeSourd, Chairman, Mr. Burton Cushing and Mr. John Merrill, presented the following candidates and they were elected to serve for the ensuing year:

President: Louis A. Wendelstein, High School, Everett, Mass.

Vice President: Hollis D. Hatch, English High School, Boston, Mass.

Secretary: William W. Obear, High School, Somerville, Mass.

Treasurer: William F. Rice, Jamaica Plain High School, Boston, Mass.

Executive Committee: James W. Dyson, Mechanic Arts High School, Boston, Mass.; John J. Quinn, Jr., Teachers' College, Boston, Mass.; Carroll H. Lowe, High School, Brookline, Mass.

The following committees have been appointed by the President for 1932-1933:

NEW APPARATUS:
John C. Packard, High School, Brookline, Mass.
Robert W. Perry, High School, Malden, Mass.
Wilfred W. Clark, Rogers High School, Newport, R. I.

MAGAZINE LITERATURE AND NEW BOOKS:
Carl W. Staples, High School, Chelsea, Mass.
Morton N. Cassidy, High School, Watertown, Mass.
Arthur G. Hildreth, Technical High School, Newtonville, Mass.

CURRENT EVENTS:
John P. Brennan, High School, Somerville, Mass.
John F. Kerrigan, High School, Salem, Mass.

COLLEGE ENTRANCE REQUIREMENTS:
Burton L. Cushing, Mechanic Arts High School, Boston, Mass.
Frederick E. Sears, St. Paul's School, Concord, N. H.
Francis E. Mason, High School of Commerce, Boston, Mass.

MEMBERSHIP:
Homer W. LeSourd, Milton Academy, Milton, Mass.
Fred R. Miller, English High School, Boston, Mass.
Roy R. Hatch, Mt. Hermon School, Mt. Hermon, Mass.

PUBLICITY:
Elliot P. Frazier, English High School, Boston, Mass.

INDUSTRIAL TRIPS:
Arthur V. Donnellan, Jamaica Plain High School, Boston, Mass.

The following new members were elected:

Active:
Winthrop S. Drury, Middlesex School, Concord, Mass.
Wallace S. Hall, High School, Somerville, Mass.
John C. Hoggs, Phillips Exeter Academy, Exeter, N. H.
Albert A. Thompson, Public Latin School, Boston, Mass.
Francis E. Reynolds, Jamaica Plain High School, Boston, Mass.

Associate:
Ira G. Newlin, Moses Brown School, Providence, R. I.
Francis E. Shea, 31 Ossipee Road, West Somerville, Mass.

REPORT OF COMMITTEE ON COLLEGE ENTRANCE REQUIREMENTS

By Frederick E. Sears, *St. Paul's School, Concord, N. H.*

At the December meeting the Committee on College Entrance Requirements was requested to make a report at this meeting on the

communication received from the Association of Science Teachers of the Middle States and Maryland. The Committee reports as follows:

1. The Committee is unanimous in endorsing the views expressed in the preliminary statements of the communication sent to us by the Association of Science Teachers of the Middle States and Maryland and agrees with their committee that there is need of a revision of the College Entrance Examination Board syllabus for the reasons given in their report.
2. The Committee is unanimous also in feeling that the plan suggested by our sister association does not offer the best or even a satisfactory solution of the problem.
3. The Committee suggests, however, that our association should cooperate with the Association of Science Teachers of the Middle States and Maryland in trying to find a solution and in presenting a plan to the College Entrance Examination Board for its consideration.

Suggestions made by members of the committee in connection with the above report:

All three members of the committee think that no one of the five divisions into which Physics is commonly divided should be entirely omitted from a requirement for first year Physics.

One member of the committee, Mr. Cushing, suggests a two years course in Physics with corresponding credit allowed by the colleges. If such a plan could be adopted it would be the happiest solution of the problem. It is very doubtful if such a plan could be put through. It might be worth trying, however.

If it is necessary to confine our efforts to a revision of the one year course the suggestion by Mr. Mason is that Sound and Light have as low a minimum as possible and that a school should major in Mechanics, Heat, or Electricity—one only of the three. There would, of course, be a minimum in these last three subjects for which all pupils would be required to prepare.

Some such arrangement is, of course, the only possible one and as a matter of fact the present requirement was designed to do something quite similar. The present requirement is, however, not definite enough in that respect, and the present style of paper does not differentiate enough between "stock" questions for part one and more difficult ones for part two.

As has been expressed by many members of the Association the form of paper which was formerly used, with five groups, was better than the present form.

If a very definite requirement was made that a pupil should study Mechanics, Heat or Electricity—one of the three—more thoroughly than the other four, and if a paper was prepared with five groups and with proper opportunity for choice in each group so that any given pupil could answer elementary questions in four groups and harder ones in the fifth it would be an improvement over the present syllabus and form of paper.

In revising the syllabus there should be introduced some new topics and some now present should be omitted.

Upon motion of Mr. Howard it was voted that the Committee on College Entrance Requirements for 1932-33 be instructed to cooperate with the Association of Science Teachers of the Middle States and Maryland in their attempt to secure a revision of the College Entrance Board Syllabus in Physics.

On motion of Mr. Miller it was voted that the Executive Committee consider the matter of returning to the old method of printing our reports in pamphlet form instead of in SCHOOL SCIENCE AND MATHEMATICS and that they be authorized to take such action as they see fit.

It was voted that the thanks of this Association be extended through Prof. Greenough, Master of Dunster House, to Harvard University for its hospitality in entertaining us at this meeting and to all who assisted with the program.

Mr. Rice showed the new Durium records published by Science Service, Inc., Washington, D. C. There are seven of these, each being a five minute speech by an eminent scientist—Millikan, Merriam, Conklin, Compton, Baekeland, Welch, Mann. A picture of the speaker with a short biography is furnished with each record and there is also a complete description of the process of manufacturing Durium records. The price of the set is three dollars.

Mr. H. D. Hatch demonstrated the Singerman's Color apparatus loaned by the Chicago Apparatus Company. This is a box containing incandescent lamps and glass filters. Overlapping circles of colored light make it possible to easily explain primary colors, complementary colors, color fatigue, and the other usual light color experiments.

ANNUAL ADDRESS OF THE VICE PRESIDENT

MR. LAWRENCE A. HOWARD, *High School, East Boston*

Mr. President, Ladies and Gentlemen:

This morning I feel deeply conscious of the honor which this association is accustomed to confer annually upon its vice-president, the privilege of addressing one of its meetings. But it seems to me that with that honor there goes considerable of an obligation. Our meetings are so few and our membership is of such a caliber that the recipient of this honor is in duty bound to see to it that he does not waste valuable time. And so I was somewhat terrified when I looked over my meager stock in trade to see what message I could possibly bring you that would justify my time allotment.

A high school teacher of physics with four or five classes a day and numerous other assignments incidental to the job is not likely to have many experiences that contain elements new to you. In my case facilities, both mental and physical, and time for research seem to be entirely lacking. Hence, I can present no ringing account of personal discovery. But sometimes when the necessary educational chores are done a bit earlier than usual I get to thinking about the values of the subject I teach and its content, about the students who come to me and what I owe them for the time they spend. I have even found my thoughts wandering to those pupils who, for one reason or another, do not spend any time there and have wondered if they ought not to. So I want to ask you to bear with me for a few minutes while I voice just a few of those random and more or less disconnected thoughts, not because I think you do not have any along the same lines, nor because I think I have better ones, but only because I may have different ones.

SOME THOUGHTS FOR THE PHYSICS TEACHER

I

In listening to recitations, in reading laboratory reports, and in correcting written tests, have you found pupils lacking in the ability

to make clear and accurate statements? I doubt if that has been an experience peculiar to my situation. And yet what can be more important than that as a tool for any job? It matters little how much a person knows, if he cannot get it across to others with clearness and accuracy he can never hope to make much of himself in any line. You may say that it is the business of the English teachers to look out for that, and so it is, but I believe that we could be of great assistance to them if we would. Physics furnishes an excellent field for training in this line. Our teaching furnishes the pupil with very definite, clear-cut principles and processes to talk about and we ought to insist that he do so in full and accurate statements, logically arranged. We should make of each recitation a short oral exposition or description and of each examination a written one.

Too many teachers, through impatience and their desire for proof that something has been learned, begin to nod the head in approval as soon as a halting word or two bearing on the correct answer are forthcoming instead of maintaining what has been popularly called a "poker face" until a complete, connected, and scientifically accurate reply to the question has been constructed. Such a procedure relieves the pupil of the necessity for developing the power of clear expression when we have a first class chance to make him do so. Of course the objection is made that this takes time, but I am inclined to think that this objection is quite invalid. It will not slow up the recitation much after the very first, and when the students understand what they have to do to make their answers acceptable. Even if progress be retarded a trifle, the lasting gain to the pupil offsets it. Moreover, so far as results in our own course are concerned, it is well to remember that incomplete or ambiguous answers may, and usually do mean, imperfect grasp of the topic being discussed, and in that case our slightly more rapid progress would avail us little. With no sacrifice to his own subject, the physics teacher can, if he will, insist on such oral and written answers to his questions that they will do more for the pupil than merely test his progress in physics. This would seem to imply a sparing use of the "true-false," the "missing word," and all other similar forms of rapid testing.

II

How many of us insist on having our pupils study the lives of the great physicists as the teachers of literature and history, for example, do for the great men in those lines? It is pretty generally conceded that a person cannot lay claim to any sort of an education unless he knows something of the great authors, statesmen, and generals. Should he not be expected to have some acquaintance with the lives of the great men of science also? Have those others made important contributions to the progress of civilization? So have the scientists. Have those others been inspired by lofty ideals? So have the scientists. Do the lives of those others serve as inspirations to youth? So would the lives of the scientists also, if they were studied.

I have always felt that the scientist has never received from the public his share of attention, and I fear that the blame can be placed

at the door of the science teacher. We do not take the time to see that they are properly honored, because we do not want to stop teaching principles and applications long enough to do it. It would introduce a human element into that mass of facts, principles, theories, and hypotheses which is physics, if we required our pupils to be able to place the great physicists geographically and chronologically, to learn of their struggles and sacrifices, and to properly appreciate their services to all mankind. If we do not undertake the job of educating the public to the point where the work of the scientists receives the recognition which it deserves then it will remain undone.

III

Are there any jobs available for which a high school course in physics can be considered a direct training? I confess that I do not know, and I suspect that most of you are in the same fix. As a rule I believe we have thought that there probably were not, if we have thought about it at all. But would it not be well to find out, if possible? I suppose that the proper method would be to make a thorough canvass of employers. It would be a laborious task and would take time, but I am inclined to think that it ought to be done in every community in order to settle the question definitely one way or the other. I presume that there would not be many, but if we found even a few it would give us additional help in our problem of the guidance of pupils and it would be something to hold out to our good students who were not going to college. It would be evidence that physics is practical in a way different from that upon which we have been accustomed to lay such stress and it would give us another talking point in our appeal to students. It almost seems as though there must be some employers in almost every community who would be glad to hire persons with a high school education who knew something about determinations of density, specific gravity, calorific value, and the like. Perhaps the ability to make accurate weighings, to read electrical and other instruments, or to measure the intensity of illumination might prove to be of value on some jobs. Possibly, also, a knowledge of some portions of physics might be desirable, at least, in some kinds of clerical and secretarial work. At any rate, I do believe we should look for a definite answer to the question.

IV

Of late years we have insisted much on the practical side of physics. We spend a great deal of time on appliances and processes which utilize the principles of the science, pointing out in this way how much our civilization depends upon it and endeavoring to make our students more intelligent users of such appliances and processes. This is all very good, and I am in hearty agreement with it. But I sometimes think we have been too busy pointing out how useful the knowledge of physical principles has been and is, and have neglected to point out specific instances of how disastrous the ignorance of those principles may prove to be. I know of no better way to impress pupils with the bearing of our subject on everyday life than to em-

phasize this latter phase. It catches their interest at once. We should warn them against possible dangerous situations and make them understand how disastrous effects may be predicted and explained through the laws of physics. I do not think we should leave it to the insurance companies and the fire departments to point out the danger in the altogether too common practice of restoring electrical current through a blown fuse by means of a coin or a bent-up hair pin. We should teach pupils that it pays to watch the insulation on their household electrical appliances and not wait for something to happen before having it repaired when breaks appear. And surely we can draw a physics lesson from the fate of some persons who, to prevent water pipes from freezing have shut off the cellar cock but have opened no faucets above. There is a lesson in heat and light in the occasional setting of a fire by the passage of the sun's rays through a fish bowl. If you watch, you will find many instances of your own knowledge where ignorance of physical principles has caused disaster and the newspapers furnish us with an up-to-date text-book. As illustrations let me quote both from my own knowledge and from my newspaper text-book.

A senior girl from our school obtained temporary employment during the recent Christmas season as a bundle girl in one of Boston's large department stores. When the knife which she used in cutting cord became too dull to work well, she cast about for a convenient whetstone, and chose the slate of a nearby electrical panel board. The operation would probably have been highly successful if the knife blade had not touched momentarily and simultaneously two of the leads. From the resulting flash and ensuing darkness the girl was fortunate to escape with no serious injury and the store with only a short cessation of activities on that floor. This girl, by the way, had not elected to study physics.

Not long ago a farmer died from a shock received when he threw a pail of water on a fire around some electric wiring in his barn. A fire in Salem was caused by the focusing of the sun's rays as they came back from the reflector of an electric heater of the "bowl" type which was on display in a show window. Within two weeks a Malden woman died from burns received when a short circuit in the cord of an electric flat iron set fire to her clothing. Three men were blown into Boston Harbor and severely burned while filling a motor boat with gasoline, the fumes from which were ignited by static electricity generated by the flow of the gasoline through a hose line.

And so it goes. I need not multiply the instances, but perhaps I ought to be sure that you are acquainted with what happened to the man who attempted to rid himself and the community of a cat by the humane method of placing it in a small box containing some sort of lethal gas. The cat's resistance to entering the death chamber necessitated some vigorous pushing on the part of the executioner. His hand slid along the animal's fur and sparks of static electricity were generated. An ensuing explosion of the gas gave the animal an indefinite reprieve and its tormentor a trip to the hospital.

V

It would be ridiculous, indeed, to spend time here attempting to justify the study of physics. I have every reason to suppose that we are all believers in our subject. But to just what extent do we believe in it? To whom do you think it should be taught?

An examination of the curricula offered by many high schools would lead one to the conclusion that it was considered essential only for those few students who wished to enter certain institutions of higher learning. Other pupils are permitted to elect it, whether they are planning a college course or not, while still others, and there are many, are not allowed to consider it at all. Their programs are too full of those other things that are supposed to be necessary.

If we are properly convinced of the value of our subject, we ought to entertain serious doubts as to the soundness of any program of study that leaves it out. If we really believe that it has all the values generally claimed for it should we not feel that it ought to be given to every high school student? I should hardly attempt to maintain that physics is the most important subject of all, but I do believe that it is quite as important as some of the studies that crowd it out of many of our curricula. In the lives of all people, college trained or not, there arise with some frequency situations which call for a certain knowledge of physical principles.

Without attempting to support this thesis further, let me come to the point I wish to make. If physics is of such value to people in general, or even of any great value, we should be doing a service to secondary school pupils by seeing to it that they take it. It is probably impossible, and perhaps undesirable, to attempt to make it a required subject for all students. I should certainly not advocate the same sort of course for all. But it might be possible to make it more widely elective, and this would be worth working for.

But whatever our success, or lack of it, in our efforts to convince the makers of curricula, there probably will be in every school some, and perhaps many, students who are permitted to elect physics. We ought to make very sure that if any of these do not choose the subject, it will not be through ignorance of its character and importance. If we have a product that is good for them we should not hesitate to try to sell it. But we and our co-workers in the science department will have to do our own advertising. There is no other way by which students are likely to be accurately informed of its merits.

It has been my experience that high school students have almost no conception of what physics is, or of what possible use it could be in after life, when they are confronted with the chance to elect it. We can hardly wonder, then, that they do not choose it in preference to some other subject with which they are more familiar. The testimony which they get from many of those pupils who are taking it, or have taken it, is not always reliable, possibly because we have failed to

make our teaching attractive or to get across the real significance of the subject. Guidance in the choice of electives by teacher-advisers is frequently faulty because of the fact that they themselves have not been trained in science and do not appreciate its values, or because they have an axe to grind for another department in the school. Likewise parents cannot be depended on to appreciate the value of our subject. And so the duty of presenting the merits of our case, if they are to be presented at all, devolves upon us.

In our school we have believed in physics sufficiently to attempt what I have been suggesting. We began two or three years ago to inform as many as possible of the students who might subsequently elect it what physics dealt with and what lasting benefits might be expected from a study of the subject. At that time we had two physics classes made up entirely of pupils who were not required to take it. That we had that many was undoubtedly due to the splendid missionary work performed by the teachers of first and second year science classes. They conducted no advertising campaign, but they did make their courses so profitable and so attractive that many of their students elected physics when the time came, not because they knew what it was except that it was more science. While this influence still continues, these same teachers now make sure, in addition, that all the members of their classes are directly and correctly informed as to the content of the course and as to the advantages to be derived from the study of physics. We have also been given the opportunity to address pupils in assemblies, and the science teachers have talked with individual students.

The net result of these combined efforts has been to increase the number of divisions made up entirely of pupils who are not required to take physics from two to six in the space of a few years. Similar results could probably be attained in any other high school if the teachers of physics were to initiate a campaign of education regarding the values of their subject, believing as sincerely as we do that in urging pupils to take the course if they can we are doing them and the community a real service.

To sum up this line of thought—we should not hesitate to advertise through the dissemination of correct information. We should not stand too much on a false sense of dignity and wait for the day when young people shall seek us out because they appreciate what we have to offer.

Before letting up on my insistence that we, as physics teachers, ought to be on the aggressive to see that our subject renders as much service as possible, I should like to comment on the proposition recently presented to this association by the Association of Science Teachers of the Middle States and Maryland.

Their introductory statement reads in part as follows: "The extraordinarily rapid growth in recent years of knowledge of those facts and principles constituting the subject matter of physics, and the numberless applications of those facts and principles in modern, everyday life make it undesirable longer to attempt a comprehensive treat-

ment of all subdivisions of physics in a one-year course in secondary schools." They then propose selective groupings covering parts only of the subject for a year's work, applicants for college entrance to be examined on the single group of their choice.

If this proposal implies that students will be taught but a part of the subject of physics, omitting some of its major subdivisions, then it is fundamentally wrong. It is but a convenient scheme to get the pupil into college with no thought of anything beyond that. If physics is of such value in life as their own statement of the problem declares, then students should have it taught to them, not in part, but in its entirety. If one year is really insufficient in which to accomplish this then what we should fight for is more time and proportionately more credit. To suggest that any major portion of our subject can be lopped off is a confession that physics is not so important as we have been wont to claim.

It is high time that we and all others should cease to look upon physics as an excuse for giving another college entrance or diploma credit. That credit should be given only as a recognition for having mastered an important and useful branch of knowledge.

Prof. N. Henry Black of Harvard University presented informally some observations on the "Teaching of Science in European Secondary Schools."

Prof. Black has recently returned from an extended trip abroad during which much of his time was spent in visiting schools in England, Germany and France where Science is taught. After discussing differences between their general systems of education and ours he dwelt upon the training and position of their teachers, their school buildings, their Science equipment, and the Science texts and experiments used. The talk was thoroughly illustrated by lantern slides and proved most interesting. Many enjoyed looking over copies of foreign text books and Science magazines which Prof. Black had with him.

In the afternoon Prof. Black again contributed to the meeting by his "Demonstration and Description of Some Interesting Apparatus Seen in Foreign Schools." The list of demonstrations follows:

FROM ENGLAND:

1. Specific Heat of Metals and Latent Heat of Steam using a Thick Calorimeter.
   (Rugby School Model—Philip Harris & Co., Ltd., Birmingham.)
2. Magnetizing Steel with an A.-C. Coil.
   (Rugby School Model—F. A. Meier.—Philip Harris.)
3. A Home-made Gauss meter for determining H according to Meier.
   (Compass from W. G. Pye & Co., Cambridge. Cobaltchrom Steel Magnets from W. B. Nicolson, Glasgow.)
4. A New Charles' Law Apparatus designed by F. C. Lay, Headmaster Wellingborough Grammar School—Dick, Son & Lewis, London.
5. A Transparent Combustion Calorimeter designed by Darling, made by A. Gallenkamp & Co., Ltd., London.

FROM GERMANY:

1. A Magnetic Shunt.
2. High Voltage Produced by Self Induction.
3. Induction Furnace.
4. Glass as an Electrical Conductor.
5. Working model of an Electric Meter.

All the above apparatus from Physikalische Werkstätten, A. G., Göttingen, Germany. Designed by Roller & Pricks.

British Agents:

A. Gallenkamp & Co., Ltd.,
17 Sun Street, Finsbury Square, London E. C. 2.

FUNDAMENTAL ADVANCES IN PHYSICS OF THE LAST TEN YEARS

By Prof. Franzo H. Crawford, *Harvard University*

I want to speak this morning about a number of important advances which have had the effect of throwing into more prominence the dual nature of both light and electrons. You are familiar with the photoelectric effect in which a quantum of energy is absorbed by a single atom with the ejection of an electron with a definite and calculable velocity. All photoelectric results imply that a beam of light may be regarded as a stream of such quanta or *photons*. These photons are to be regarded as bundles of energy, the amount of energy in each depending on the frequency, according to Planck's well-known equation—energy is equal to h times frequency.

In 1922 as a result of researches on the scattering of X-rays Professor Arthur Compton in Chicago was able to announce another result which is most readily explained by regarding photons as definite units of energy which in their interactions with matter obey the laws of ordinary particle dynamics. In these experiments a beam of X-rays was allowed to fall upon, for example, a piece of carbon, and the X-rays scattered from the carbon were analyzed with a crystal spectrometer. It was found that the rays scattered in various directions from the original beam involved two different wave lengths, (1) the original wave length and (2) a slightly longer one. This slightly longer wave-length corresponds to a lower frequency and consequently to photons of reduced energy. As a matter of fact, assuming the photon to be a particle which collides with the atom and ejects an electron, the process obeying the ordinary laws of the conservation of linear momentum and energy we should expect the scattered photon to have less energy than the incident photon, due to the fact that the electron has carried some of it off. The photons which are scattered by the atom as a whole have an analagous reduction, but due to the great mass of the atom the energy which it carries away as a result of the collision is quite negligible. We thus are able to account for the two scattered wave-lengths, and calculations show that the difference in these two scattered wave-lengths varies with angle in precisely the way we expect it to.

Some six years later, in fact, in 1928, Raman, in India, studying the light scattered from liquids, observed that in many cases very faint lines were observed in positions on either side of the original line which he was using. These displaced lines were separated at intervals which could be measured and which when interpreted in terms of energy changes implied that the incident photon had either *given up* some energy to the molecule as a whole or *abstracted* some, and consequently came off with either less or more energy than it originally possessed (the result of course being some light scattered at longer wave lengths and some shorter than the original incident beam). This in itself, while interesting, would not be so important were it not connected directly with certain properties of the scattering molecule which can be investigated directly. These energy changes which the molecule undergoes can be, in fact, studied most readily by examining the infra-red spectrum of the molecule in question. Here it is found that the sizes of the quanta which the molecule can absorb or emit correspond with the energy displacements observed in the Raman effect, and that in general the same energy changes can be investigated either by the Raman effect or by infra-red absorption measurements.

These two quite different types of experimental results indicate that in the interaction of light with matter we must regard the light as behaving as though it consisted of bundles of energy which obeyed the laws of the conservation of energy and the conservation of linear momentum.

On the other hand, certain other lines of investigation have tended to show that electrons, which hitherto had been regarded as most definitely corpuscular in nature might also under proper conditions exhibit wave properties; consequently with the necessity of regarding light as being simultaneously a wave motion and a stream of corpuscles, there arises the necessity of regarding electron-streams as not only streams of particles but as beams possessing a certain characteristic wave-length. These experiments were begun by Davisson and Germer and involved the study of the reflection of electrons from crystals of nickel. They found that in case a single crystal was used and electrons of definite velocity allowed to impinge on it, that reflection took place according to the same laws which govern the reflection of X-rays from crystals. It was necessary, to account for these experiments, to assume that the wave-length associated with the beam of electrons was determined by $\frac{h}{mv}$ where m is the mass and v velocity of the electrons and h is Planck's constant. On this assumption it was possible to repeat all of the diffraction experiments characteristic of X-rays, the difference being that instead of a beam of X-rays a beam of electrons of a definite velocity (and hence characteristic wave-length) was used. The results of the diffraction of electrons by single crystals, the equivalent of powdered crystals, and ruled gratings, have all assigned to the electron beam the same characteristic wave-length. As a result of such experiments we are forced to conclude that electrons also lead a sort of double life—

sometimes behaving as Dr. Jekyll and at others as Mr. Hyde.

Now of course it is rather difficult to give any interpretation of what this wave-length means or of what is actually "waving." We may say that the wave motion associated with the motion of a stream of electrons must be regarded merely as a "ghost wave" which accompanies the beam of electrons and tells the electrons where to go. This is analagous to the interpretation of ordinary diffraction in the case of light. Here we must regard the wave theory as being a mechanism or a time-table which tells the individual photons where to go, or rather tells how many photons shall go to each place in the diffraction pattern. Unfortunately it does *not* enable us to tell where a given photon will go nor on the other hand is it possible to predict in the case of the beam of *electrons* passing through a crystal where any single individual will go. The wave theory applied to this beam of electrons merely enables us to calculate how many electrons will go to a given point of the pattern. In this sense the above types of experiment have a *similar* sort of indefiniteness; apparently this is a very fundamental type of uncertainty and one which no refinement of observation can ever remove.

Now as soon as there was direct experimental evidence of some sort of a wave motion being associated with the motion of electrons it was clear that this same property should play a very important part in determining the nature of the electronic motions in atoms and it was from this standpoint that the wave mechanics of atoms was built up. You are familiar with the general aspects of the Bohr-Rutherford theory in which, say in the case of hydrogen, we have a small positive nucleus around which an electron moves in definite orbits. Particular orbits which are permissible for the electron are determined by certain quantum conditions and it is assumed that no other orbits except those satisfying these quantum conditions represent *stable* motions of the system. It was always, however, very difficult to form any physical picture of the meaning of these quantum conditions and to have a feeling for the stability for certain orbits as against closely neighboring ones. From the standpoint of the wave theory of electrons DeBroglie in his thesis presented in Paris in 1923 indicated that we should form a picture of the stability of certain orbits as against others, by regarding the electron moving around in an orbit as having associated with it these electron waves which were of such length as to form *stationary waves* around the atom. In fact, taking the known size of the Bohr orbits and the relation $\lambda = \frac{h}{mv}$, only those orbits can be stable for which there can be contained in the orbit an integral number of standing electron waves. That such a state might be stable seems quite plausible from our knowledge of vibrating mechanical systems, such as vibrating chords, broken up into segments with nodes and antinodes, the motion being stable and determined by the constants of the system. Actually the details of the mathematical theory are rather complicated, but in brief they lead us to pictures of the distribution of electrons around an atom which

are much less definite than the Bohr orbits, but which in the case of orbits of a very large diameter agree qualitatively with the older Bohr picture.

Wave mechanics furthermore gives us a picture of the actual process of changing from one stationary state to another. We imagine the state of stationary waves which is characteristic of one state slowly changing to the state characteristic of another energy state. During this process of change we have two sets of vibrations occurring simultaneously and there is therefore a characteristic "beat note" the frequency of which is numerically equal to the difference in frequency of the two standing wave vibrations, and it is this "beat note" which we actually see as light. Thus although we can measure the "beat note" we have no possibility of measuring other than indirectly the actual frequency of vibration of the electron itself.

It is the completeness and satisfying nature of the picture of atomic relations which is thus presented to us as well as the way in which it utilizes experimental facts gathered from entirely different sources which makes the new quantum mechanics such a notable advance in atomic investigations.

RECENT DEVELOPMENT IN THE FIELDS OF ELECTRONICS AND ACOUSTICS

By MR. FREDERICK V. HUNT, *Cruft Laboratory, Harvard University*

A. NEW ELECTRONIC DEVICES AND THEIR USES

In this discussion, we will begin with the invention of the three electrode thermionic tube, pass rapidly through the first twenty years of its development and then examine a little more closely the progress made during the last five years.

Let us confine our attention first to the radio tubes, and sketch through the first twenty years in episodic fashion. Beginning with the introduction by DeForest in 1907 of the control grid we come to the development in 1913 of the technique of producing high vacua signalized by the invention of the mercury diffusion pump; the introduction of the oxide cathode by Wehnelt in 1914; the heroic and successful effort to establish trans-oceanic telephone conversation in 1915,—I call this heroic because the largest tubes then available were of 25 watts output, and it was necessary to operate several hundred of them in parellel. The war furnished some interruption of this development program, but brought in its wake considerable standardization of production methods, so that by 1920 tubes of the 201 type became available to the public in considerable quantity. During 1921 tubes were built in higher powers up to 1 kilowatt, but it was not until 1922 that Housekeeper learned how to seal copper to glass and the way was paved for the first significant development in high power tubes with water cooled anodes. These tubes formed the basis of the experiments in 1923-25, that led to the successful inauguration of the present transatlantic telephone service in 1928.

The year 1922 was marked by the discovery of the manufacturing

process for producing thoriated tungsten filaments. This led to the design of low-power tubes designed for dry cell operation and gradually extended through the whole family of tubes, resulting in material reductions in filament consumption.

Shortly after 1925 the public demand for better fidelity and increased power in radio reception spurred the development of tubes designed for a.c. operation. Beginning with the 26 type of tube in 1926, this development has continued with the general introduction of indirectly heated cathodes.

There is still much demand for low power tubes, however, and recent development of new core materials and improved methods of applying the oxide coating have resulted in the design of a new series of tubes for two volt filament supply. These tubes, consuming only 120 milliwatts in the filament, have a mutual conductance, which makes them almost exactly comparable to the old 201-A type tube consuming 1250 milliwatts in the filament,—truly a significant step forward in cathode efficiency. This series is now offered in all types including screen grid, output power, and pentode power tubes.

The manufacturers of automobile radio sets wanted a tube that could be used with the automobile storage battery. The old six volt tubes would hardly do because of the severe generator ripple introduced by the auto generator which is always charging the battery while the engine is running. This led to the design of a new series of tube for direct current filament supply, but with indirectly heated cathodes. Taking advantage of the new improvements in cathode construction these tubes remain as powerful as the alternating current tubes designed for larger sets, but with significant reductions in filament heating power.

Here this matter rests for the moment, but it is interesting to notice in passing how each development of a tube for a new power supply has carried with it actual improvements in efficiency.

Other changes in internal structure even more remarkable than the improvements in cathode efficiency have taken place within the past few years. The screen grid tube, the variable mu screen grid tube, the pentode, and finally the variable mu pentode are examples of this.

The situation which gave rise to the introduction to the screen grid tube may be briefly summarized in the following manner: If we use the ordinary three electrode tube to amplify a radio signal there will be, of course, a great deal more power in the output circuit of the tube than there was in the input circuit, say 10 times as much. It is necessary to carefully shield this output circuit from the input circuit, lest an odd 10 per cent of the power leak back to the input circuit and cause the system to break into spontaneous oscillation. But there is one path by which feedback can take place which cannot be blocked by any kind of external shielding, and that is the path through the actual electrostatic capacity existing between the control grid element and the plate. This capacity is small, but the frequencies involved are high, and the limit by which a signal can

be amplified in a single stage is set by this feedback effect through the tube itself. Circuits were devised to neutralize this effect,—the Neutrodynes that flourished in 1924-27, but a more elegant way to accomplish this result is to actually introduce within the tube itself an additional electrostatic shield between the control grid and the plate which eliminates the feedback at its source. This is the screen grid. By its use the tubes can be designed to yield much more amplification per stage. To be sure, tubes could have been designed for that before, but the inherent tendency to self-oscillation would have prevented their useful application.

If it is possible to secure such high amplification per stage with these screen grid tubes then why not use them to drive the loudspeaker and eliminate one or two stages of audio frequency amplification? Of course this was tried, but with little success, because the voltage across the output device could not be permitted to exceed certain values without running into another difficulty. When the large alternating voltages across the load cause the actual potential on the plate to become less than the potential on the screen, then secondary electrons, which may be knocked out of the plate by the impact of electrons from the filament travelling at high speed, will not return to the plate but will be attracted to the more positive screen. Hence the plate current will decrease and may actually reverse. Thus, there exists a serious limitation on the available output from the screen grid tube due to secondary emission from the plate. This is of no great importance for radio frequency amplifiers, but it prevents the efficient application of the tube in high powers.

The pentode tube was developed to meet this difficulty in the application of screen grid tubes for power output devices. A fifth electrode was introduced between the screen and the plate, called a suppressor grid. This extra electrode was permanently connected to the filament, the external connections to the tube remaining unchanged. Now, when the plate potential drops to a low value, the plate is still the most positive element in its immediate neighborhood, and the secondary electrons produced by electron impact are immediately drawn back to the plate. Thus the advantage of the screen grid are retained for output power use, and the radio season just past saw many sets offered to the public in which the detector itself was able to drive the output power tube. The commercial advantages of such simplification are obvious. There is one drawback, however. The spacing between the plate current curves, taken for constant increments of grid voltage, is not the same for small as for large grid voltages. This non-linearity results in the production of harmonics in the output current that were not present in the original signal applied to the grid. Regrettably, we must admit that in spite of its advantages in power output for a given available signal, the purity of this output is decidedly inferior to that produced by the less efficient three electrode output tubes.

The next development in the field of radio receiving tubes is the variable mu screen grid tube. For perhaps the first time in radio tube history an engineer decided to deliberately change the shape of

the plate current-grid voltage curve, and credit for the development belongs to Ballantine and Snow of the Radio Frequency Laboratories. The need for this tube arose from the following situation: one of the most effective and convenient methods of controlling the volume of the output signal from a radio receiver, or the more usual problem of preserving the output signal constant for widely varying input voltages, consists in altering the grid bias of the radio frequency amplifier tubes. Now when the grid voltage is increased far enough negatively, for the ordinary type of screen grid tube, only the peaks of the applied input grid voltage will cause plate current to flow. This results in the production of serious distortion in the audio frequency output. Mathematically the amount of this distortion can be expressed in terms of the abrupt curvature of this plate current-grid voltage curve near the point of cut-off. By altering the construction of the control grid it was found possible to produce a plate current-grid voltage relation in which the control grid bias could be varied over very wide limits without introducing any abrupt curvatures. This can be accomplished by a number of methods, one of the simplest of which consists in merely leaving a gap in the center of the control grid. For small negative grid voltages the tube functions normally as a fairly high mu tube, but as the grid bias becomes more negative the ends of the grid cut off completely, permitting electrons to reach the plate only through the gap. This functions as a large mesh grid, or one producing low mu. Hence the name "variable mu." The result has been that the range of input signal which may be controlled has been increased by a factor of about 25, thus eliminating the necessity for a local-distance switch on the set and greatly facilitating the use of automatic volume control systems.

The next logical step was to combine the improved control characteristics of the variable mu tube with the increased output made possible by the addition of a suppressor grid to the usual screen grid assembly, the variable mu pentode. So far, this has only been offered commercially as a six volt tube for automobile use, but it will undoubtedly be made available in other types soon.

One further development may be briefly mentioned, although it is so very new that it cannot properly be said to have happened yet. This is the cold cathode tube. Instead of using a hot filament emitting thermionically as a source of electrons, the tube is filled with some inert gas at low pressure and a glow discharge is maintained between two electrodes. The electrons freed by this ionization process may then be acted upon by the potentials applied to a control grid and the plate in the usual manner. Rumors abound concerning developments along these lines but the difficulties involved are considerable and nothing of the sort has reached the commercial market yet. For example, the gas pressure must be carefully regulated so that the glow discharge occurs only between the two electrodes constituting the cathode structure. Furthermore, there are, of course, positive ions in the discharge column, and these may flow to the control grid if it is maintained at a negative potential as is the case in conventional tubes. This in itself would not

hinder the functioning of the tube, but it might seriously affect the introduction of the tube into the usual radio circuits.

Of especial interest to research workers are two new tubes recently developed in the laboratories of the General Electric Company for the measurement of extremely small voltages and currents. One of these, the FP-54, is intended for the measurement of extremely small direct currents. The method to be followed consists in introducing a very high resistance between the grid and filament of the tube, and permitting the unknown current to flow through this resistance; but as we increase the resistance in the grid circuit we eventually find that there is a small current flowing from the grid of the tube which also produces a voltage on the grid, and eventually masks the effect of the current we desire to measure. The problem in tube design then is to reduce this undesired grid current. When this problem is attacked seriously a whole new group of phenomena arises which has been completely negligible before. For example, the light from the hot filament may produce a certain amount of photoelectric emission from the grid wires. Still more surprising is the fact that the electrons striking the plate may produce very soft X-rays, which cooperate photoelectrically to produce emission from the grid wires. The tube must be operated at very low voltages so that none of the residual gas present can be ionized. Ordinary surface leakage must be kept very low. Building along the lines indicated by these considerations we have the FP-54 employing a thoriated tungsten filament to secure emission at low temperature and low light intensity, with a plate voltage of only six volts to reduce X-rays and ionization, and with the control grid supported on quartz beads to reduce surface leakage. Employing two such tubes in a special circuit arranged to minimize the effect of battery fluctuations it is possible to detect a current as small as 5 times 10^{-18} amperes, corresponding to approximately 30 electrons per second.

We will now turn our attention to the field of rectifiers. The thermionic tube was used by Fleming as a rectifier even before the introduction of the third electrode as a control element, but it was not until the development of apparatus for producing high vacua that the device found its proper place as a rectifier for high voltages on a power scale. It has found its place, however, and has become one of the most reliable sources of high voltage. Recently, development has taken what at first sight might seem a step backward, by deliberately introducing into the rectifier a gas. Most commonly this is mercury vapor. If, in addition, a source of electrons is present, such as a hot filament, and if the current through the device is limited to that which can be emitted from the filament, then the voltage drop across the tube assumes a low value of 15 volts or so, and becomes independent of the current. Furthermore, since there is a large cloud of positive ions in the vicinity of the cathode and migrating toward it, any space charge due to the emitted electrons is annulled, and the electrons can escape through small apertures in the cathode. Thus, we have the opportunity of constructing a cathode

which may be elaborately heat insulated, and so produce large thermionic emission currents running up to 100 amperes or more without the expenditure of excessive power for heating the cathode. Rectifiers have been constructed along these lines showing a total efficiency considerably higher than that of rotating machinery, without the attendant maintenance difficulties.

Closely related to these mercury vapor rectifiers is the thyratron family, which differs only by the addition of a control grid. If this grid is maintained at a sufficiently negative potential the arc discharge in the gas cannot be set up, but if the grid voltage is reduced below a critical value the current to the plate immediately jumps to its full value, and the grid has no further control over the discharge. It may prevent the discharge, but once started, it cannot stop it. This is caused by the formation around the grid wires, as soon as the discharge commences, of a sheath of positive ions which effectively shield it from any further influence on the current. The only way to stop the current is to interrupt the plate voltage. Of course, if alternating voltage is applied to the plate this will occur every cycle. Hence the grid may reassume control during any one of the negative half-cycles. Thus the device is an on-or-off relay capable of handling extremely large currents. If an alternating voltage is applied to the grid as well as to the plate the device may be used to secure a continuous control of plate current. This continuous control may be effected by altering the phase relations between grid and plate voltages. A number of circuits are available for accomplishing this, one of which is set up on this table. A cathode ray oscillograph is connected to show the manner in which the plate current is varied by changing the phase of the voltage applied to the grid.

This cathode ray oscillograph is deserving of some comment, especially as you may eventually have one of its first cousins in your home in the form of a television receiver. The construction of the improved type of cathode ray tube, developed by Zworykin, may be described as comprising a hot cathode emitting electrons which are successively accelerated by three electrodes, finally to impinge on a fluorescent screen. The significant improvement in this device is the fact that the focusing of the electron beam has been made a function only of the ratio between the potentials applied to two of the electrodes while the potential of the third may be utilized to control the amount of current flowing, and hence the brilliancy of the illuminated spot. Thus, we have all the elements of a television receiver, a luminous spot which may be moved rapidly over a receiving screen, and at any instant modulated in accordance with an incoming signal.

Let us turn our attention now to the field of light sensitive devices. The first type, whose resistance is a function of the light falling on it, we will pass over as possessing few, if any, advantages over one or the other of the other two types. The second, the true photoelectric tubes, are of extreme theoretical, as well as practical interest. Recent researches during the past two years have increased the sensitivity by a factor of almost ten, as well as providing extreme flexibility in locating the peak of maximum response. For example,

a platinum photo-cell is being used in this laboratory for measurement of the intensity of spectral lines in the ultra-violet, while a cell employing caesium has been used to make sextant observations on the sun through fog so heavy that the disc of the sun could not even be seen with the unaided eye. Equipped with proper filters these cells may be almost exactly matched to the optical visibility curve, and they are being widely adapted in the field of photometry and color comparison.

The third class of light sensitive cells is exemplified in a product recently offered by the makers of Weston instruments, called the Photronic Cell. It is photovoltaic in character requiring no batteries for its operation, and furnishing in moderate illumination sufficient current to operate relays directly. Because of its long life, rugged construction and good sensitivity it bids fair to become a large factor in the field of light sensitive devices. A demonstration model of this device is arranged here to show in crude fashion how these cells may be adapted to the control of schoolroom illumination.

It is hopeless to attempt to outline the uses for these light sensitive devices. Already they have been applied to everything from sorting beans to detecting burglars. They apparently can be made to do anything that a man with one good eye can do except think, and this distinction is frequently negligible.

B. Acoustics

As an introduction to the subject of architectural acoustics we may begin by describing a unit of sound intensity that has proved convenient. This is the decibel. It is a unit by which two sounds differing in intensity may be compared, and is defined as ten times the common logarithm of the ratio of the two intensities. Thus if one sound is 100 times as intense as another, the logarithm of their ratio is 2 and the sounds are said to differ in sound level by 20 decibels. Being a logarithmic unit it will be immediately apparent that this is a convenient method of measuring sounds because the ear hears logarithmically; and it is furthermore of convenient size because psychological tests have established the fact that the "just noticeable difference" in sound intensity which the average ear is able to distinguish is almost exactly 1 decibel. Thus we may prepare a chart and represent the whole range of audible sounds on a scale running from zero to slightly over 100.

The problems of the acoustical engineer are many and varied, but it is significant that one of the most trying problems concerns itself not with the production of sounds but with the fate of these sounds after the source has stopped producing them. In other words, reverberation. If I should sing, and succeed in producing a sound level of 50 d.b. on the average throughout this room, and then suddenly stop singing, something must happen to the sound energy distributed throughout the room. Under most conditions there is very little absorption in the air itself, and practically all of this energy must eventually be dissipated at the bounding walls of the room, by successive reflections from those walls. It follows that the length of

time during which you are able to hear this residual sound will depend upon how many times it must be reflected from the walls before the average intensity falls below the threshold of hearing, and the length of time ensuing between successive reflections. The first factor involves the absorption coefficient of the wall materials, and the second the size of the room. We may express this by a simple equation

$$T = kV/a$$

where T represents the time required for the residual time to decay by 60 d.b., V is the volume of the room, a the average absorption coefficient, and k is a constant depending upon the units involved.

This reverberation formula has been the chief tool-in-trade of the acoustical engineer for many years. By its use we may calculate in advance of construction what the acoustical performance of an auditorium will be, and hand-in-hand with the architect plan for good hearing. For, of course, there is an optimum value for this reverberation time. If it is too long, then the sound of one syllable will persist and prevent the listener from hearing the next. On the other hand, if it is too short, corresponding to a dead condition of the room, it may be impossible for the speaker to produce enough sound intensity to be properly heard in the remote corners of the auditorium. Experience and tests have dictated optimum conditions for both speech and music, and it lies with the acoustical engineer and the architect to proportion the volume and absorbing areas so that these conditions are attained. This room, although the treatment is well concealed, has been carefully treated. The rear ceiling panels are not solid plaster but consist of a thin linen covering laid over absorbing panels of hair felt. Without such treatment the room was thoroughly unsatisfactory for classroom lectures. As Professor Pierce once said, "It is not our teaching that is at fault, but our acoustics."

The past few years have seen a myriad of new materials of high sound absorbing power offered to the engineer. Ten years ago the only absorbent materials readily available were felt and cloth hangings. Now you may obtain special acoustical plasters with absorption as high as twenty per cent, several materials of porous nature such as Celotex, which may be observed on the ceiling of the hallways of our Research Laboratory, and other materials adapted to various decorative schemes.

One cannot study the recent work in this field without paying some tribute to the motion picture industry. The introduction of the talking pictures has contributed most effectively, perhaps, by enlisting the active interest of a large body of engineers who are not only competent but well supplied with equipment and funds. One by-product of this interest has been the development in the Bell Telephone Laboratories of a reverberation meter. This is, in effect, an electrical ear whose threshold of hearing can be shifted over a wide range of sensitivity. It is arranged with an automatic recording mechanism whereby a complete curve of sound decay against time can be plotted in a few minutes. This device furnished the investi-

gators at once with a tool which eliminated the personal variations which always creep into reverberation measurements made by ear. Furthermore it gave additional information that could not be secured by the older method. For example, it was learned that sound may decay at two different rates in the same room, a phenomenon of multiple decay first reported by Eyring. Imagine two rooms adjoining but with a door open between them. Let one be a very live reverberant room and the other a rather dead room with high absorption. Now, if we produce a noise in the live room a certain amount will pass through the door and fill the dead room, until a steady state is reached. If the sound source is stopped the sound in the dead room will at first decay rapidly due to the high absorption, until after a time the only sound in the dead room is that leaking in through the door from the live room, where the sound has been decaying slowly. Thus the sound decay in the dead room coupled to the live room is at first, rapid, then slow. This is not a rare phenomenon because the door between these two rooms may very well be a radio door, or a phonograph door, and the situation is exactly analogous when a sound is produced in one room and then reproduced in another. Much work has been done on this problem by the motion picture engineers, and more will be done, for the complete account of the psychological reactions to these various types of sound decay has not been given.

One more research in this field may be cited in concluding with this section. It concerns an investigation of that exact quality of the sound which produces the impression of "liveness" in a room. One interesting contribution to the question has been made by R. L. Hanson of the Bell Telephone Laboratories. We have been talking about the decay of sound as though it were perfectly uniform. Usually, this is not the case. The sound reflected from the walls interferes, and we actually have a complicated pattern of sound intensity in the room with points of maximum and minimum intensity separated by only a few inches. Averaged throughout the room, the intensity decays at a nearly uniform rate, but we can only listen with our ears at two points very close together. Hence during the decay of sound there may be, and practically always is, a marked shifting of this interference pattern, so that we have superimposed upon the uniform decay rapid fluctuations of the instantaneous sound intensity. It is this fluctuation of the sound intensity that produces the psychology impression of "liveness" in a room. The experiments which were devised to establish this fact were extremely ingenious, and consisted in producing synthetic decay sounds by impressing the output of an ordinary oscillator upon a telephone receiver, and then modulating the oscillator in various ways that could be accurately controlled. It was found that the amplitude of these fluctuations contributed chiefly to the concept of "liveness," while the actual rapidity of the fluctuations contributed chiefly to the impression of size. The actual conditions in a room that produce these rapid fluctuations are similar to the conditions that produce long reverberation time, but the correlation is not complete and, indeed, appears completely accidental. The psychological mechanism is, of course, still obscure,

but this appears to be a significant step towards its eventual explanation.

The latter part of the afternoon was spent in the research laboratory in an inspection of its equipment and some of the researches under way. So many stayed for this that it was necessary to divide into several large parties which were personally conducted by members of the staff. It was a great treat for the members of the Association present to have the opportunity to see this work at first hand and our thanks are due to all who received us so cordially.

THE THIRTEENTH ANNUAL MEETING OF THE NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS, WASHINGTON, D. C., FEB. 19-20, 1932

The thirteenth annual meeting of the National Council of Teachers of Mathematics was held at the Hotel Raleigh, Washington, D. C. The following papers were presented: "Curriculum Adjustments," by Mr. William C. Myers, Washington, D. C.; "A Comparative Study of The Teaching of Mathematics in the United States and Germany," by Professor William D. Reeve, New York City; "Improving America's Mathematics," by Mr. Harry C. Barber, Exeter, N. H.; "What Do We Owe to the Brighter Pupil," by Miss Beulah I. Shoesmith, Chicago, Ill.; "Regents and College Entrance Board Examinations in Mathematics," by Professor W. S. Schlauch, New York City; "What Mathematics Means to the World," by Professor E. R. Hedrick, University of California at Los Angeles. All of the above papers will appear in forthcoming issues of The Mathematics Teacher.

Three new standing committees were established: (1) Committee on Individual Differences; (2) Committee on Geometry; (3) Committee on Policy, which is to formulate a body of *first principles* that should govern the teaching of secondary mathematics. The Committee on Cooperation with Official Examining Boards was continued for another year as well as The Committee on Handbook in Mathematics.

The results of the annual election are as follows: President—Mr. William Betz, Specialist in Mathematics, Rochester, New York; Second Vice-President—Mary A. Potter, Supervisor of Mathematics, Racine, Wisconsin; Directors—Mrs. Elsie P. Johnson, High School, Oak Park, Illinois; Mr. John P. Everett, State Teachers College, Kalamazoo, Michigan; Mr. Raleigh Schorling, University of Michigan, Ann Arbor, Michigan.

EDWIN W. SCHREIBER, Secretary.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON,

State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

LATE SOLUTIONS

1209. *Margaret Jean Sinclair, Waukegan, Ill., W. W. Gorsline, Chicago, Ill.*

1206. *Harry Williams, Fort Collins, Colo.*

1210. *M. H. Cohen, New Bedford, Mass., W. W. Gorsline, Chicago, Ill.*

1207. *W. W. Gorsline, Chicago, Ill.*

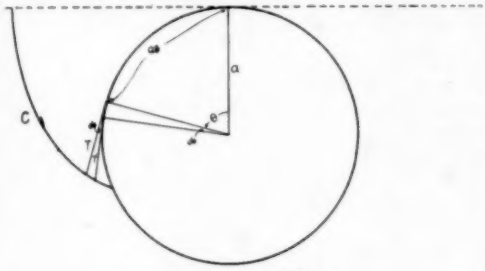
SOLUTIONS OF PROBLEMS

Editor.—Persons sending in solutions should read carefully the instructions about the form of the solutions and the ink-drawn figures. Many times, a good solution is received, but poorly arranged and no india-ink figure given.

1211. *Proposed by Stewart W. Taylor, Gary, Ind.*

Given a circle of radius a, and a taut string of length b attached to the circumference. Find the area that may be swept out of the string in the plane of the circle. Take $b < \pi a$ to eliminate the discussion of double areas. The required area lies external to the circle.

Solved by Guy C. Lentini, Boston, Massachusetts.



Let θ be the variable angle through which the radius turns as the string unwinds.

An element of area will be included between two tangents T and T′ and the piece of the curve C included by the tangents.

Then $dA = \frac{1}{2}\,T^2\,d\theta$, where $T = b - a\theta$

$$A = \tfrac{1}{2}\int_0^{\frac{b}{a}} (b - a\theta)^2\,d\theta$$

$$= \tfrac{1}{2}\int_0^{\frac{b}{a}} (b^2 - 2ab\theta + a^2\theta^2)\,d\theta$$

$$= \tfrac{1}{2}\left[b^2\theta - ab\theta^2 + \frac{a^2}{3}\theta^3\right]_0^{\frac{b}{a}}$$

$$= \tfrac{1}{2}\left[\frac{b^3}{a} - \frac{ab^3}{a^2} + \frac{a^3 b^3}{3\,a^3}\right]$$

The total area swept out by the string will consist of a semi-circle with radius, b, and two equal elements of area such as dA.

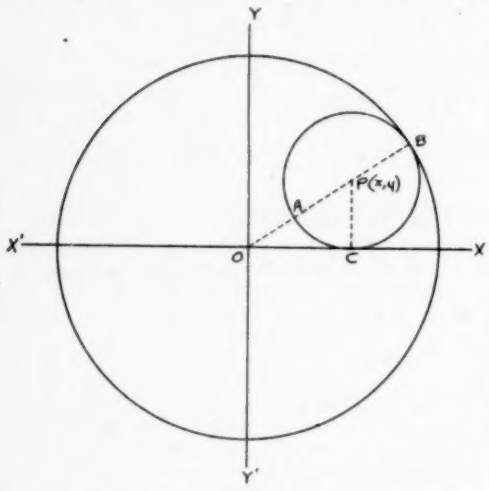
$$\therefore \text{Total area swept out by string} = \frac{\pi}{2}b^2 + 2\left(\frac{b^3}{6a}\right) = b^2\left(\frac{\pi}{2} + \frac{b}{3a}\right)$$

Also solved by Boris Garfinkel, Buffalo, N. Y.; A. J. Patterson, Wheeling, W. Va.; and W. E. Gorsline, Chicago.

1212. *Proposed by W. E. Batzler, Battle Creek, Mich.*

Find the equation of the locus of the center of a circle which is tangent to a given line segment and also tangent to the circle on that line segment as a diameter.

Solved by Charles W. Trigg, Los Angeles, Calif.



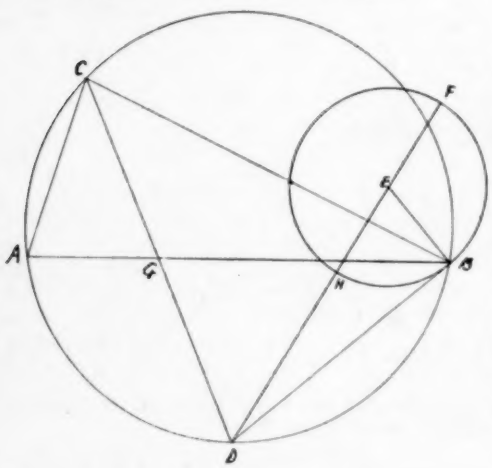
Let the length of the line segment be $2a$.
Then the radius of circle $O = a = OB$.
In circle P, AP, PB and PC are radii.
The locus of the point $P(x,y)$ is required.
In the first and second quadrants $OP = a - y$.
In the third and fourth quadrants $OP = a - (-y)$.
Hence, as OPC is a right triangle,
$OP^2 = OC^2 + PC^2$
$(a \pm y)^2 = x^2 + y^2$
Expanding and simplifying yields the required locus, (two parabolas) $x^2 \pm 2ay = a^2$.

Also solved by W. E. Buker, Leetsdale, Pa.; A. J. Patterson, Wheeling, W. Va.; Leo A. Aroian, Fort Collins, Colo.; Boris Garfinkel, Buffalo, N. Y.; Guy C. Lentini, Boston, Mass.

1213. *Proposed by A. J. Patterson, Wheeling, W. Va.*

Construct a plane triangle having given the base, the vertical angle and the bisector of the vertical angle.

Solved by W. E. Buker, Leetsdale, Pa.



Given base AB, $\angle C$, and bisector t_c.
To construct triangle ABC.
Construction:
With AB as base construct the arc which is the locus of C. Locate D, the midpoint of arc AB subtended by angle C.

Draw DB. At B erect BE perpendicular to DB and equal to one half of the bisector t_c. With E as center and EB as radius draw circle. Now draw DE cutting circle E at H and F. Now with D as center and DF as radius describe arc cutting original arc in C. Then triangle ABC is the required triangle.

Proof: Draw CD cutting AB in G.
In triangles BCD and BGD,
$\angle DCB = \angle DBG$ (each is measured by one half the equal arcs DB and AD).
Since there is a common angle at D, the triangles are similar.
Hence $CD:BD = BD:DG$ (1)

But since DB is a tangent and DF a secant to circle DHF, FD:BD = BD:DH(2)

But, by construction, FD = CD, so, by (1) and (2) DG = DH

Hence, CG = FH, and so triangle ABC is the required triangle.

Also solved by Joseph L. Stearn, Washington, D. C.; R. T. McGregor, Elk Grove, Calif.; Daniel Kreth, Wellman, Iowa.

1214. *Proposed by R. T. McGregor, Elk Grove, Calif.*

Find the sum to infinity of the series

$$1+\frac{2^2}{\lfloor 2}+\frac{3^2}{\lfloor 3}+\frac{4^2}{\lfloor 4}+\ldots$$

Solved by H. D. Grossman, New York City, New York.

$$1+\frac{2^2}{\lfloor 2}+\frac{3^2}{\lfloor 3}+\ldots$$

$$=1+\frac{2^2}{\lfloor 1}+\frac{3^2}{\lfloor 2}+\ldots+\frac{(n+1)^2}{\lfloor n}+\ldots$$

$$=1+\frac{2^2}{\lfloor 1}+\sum_{n=2}^{\infty}\frac{(n+1)^2}{\lfloor n}+\ldots$$

$$=1+\frac{2^2}{\lfloor 1}+\sum_{n=2}^{\infty}\left[\frac{1}{\lfloor n}+\frac{3}{\lfloor n-1}+\frac{1}{\lfloor n-2}\right]$$

$$=\frac{1}{\lfloor 0}+\left(\frac{1}{\lfloor 1}+\frac{3}{\lfloor 0}\right)+\sum_{n=2}^{\infty}\frac{1}{\lfloor n}+\sum_{n=1}^{\infty}\frac{3}{\lfloor n}+\sum_{n=0}^{\infty}\frac{1}{\lfloor n}$$

$$=\sum_{n=0}^{\infty}\frac{1}{\lfloor n}+3\sum_{n=0}^{\infty}\frac{1}{\lfloor n}+\sum_{n=0}^{\infty}\frac{1}{\lfloor n}, \text{ if the series is summable}$$

$$=5e$$

Also solved by Leo A. Arvian, Fort Collins, Colo.; and Frank B. Allen, Sparta, Ill.

1215. *Proposed by W. E. Buker, Leetsdale, Pa.*

Evaluate $\operatorname{Lim}_{x\to o}\dfrac{e^{-\frac{1}{x^2}}}{x^n}$

Solved by Dwight Gunder, Fort Collins, Colo.

Let $y=\dfrac{e^{-\frac{1}{x^2}}}{x^n}$, then $\log y=-\dfrac{1}{x^2}-n\log x$, or $\log y=-\dfrac{1+nx^2\log x}{x^2}$

In evaluating the limit of the above fraction, $x^2\log x$ is found to indeterminate. By use of calculus, we find that the

$$\operatorname{Lim}_{x\to o} x^2\log x=\operatorname{Lim}_{x\to o}\frac{\log x}{x^{-2}}=\operatorname{Lim}_{x\to o}\frac{\frac{1}{x}}{-2x}=\operatorname{Lim}_{x\to o}\frac{1}{-2x^2}=-\infty$$

$$\text{Then the } \operatorname{Lim}_{x\to o}\frac{1+nx^2\log x}{x^2}=\operatorname{Lim}_{x\to o}-\frac{1}{x^2}=-\infty$$

Since $\operatorname{Lim}_{x\to o}\log y=-\infty$, $y=0$.

Also solved by the proposer.

1216. *Proposed by E. de la Garza, Brownsortles, Texas.*

Solved by H. D. Grossman, New York City.

Find four consecutive integers whose product is 24024.

Solution: Since $\sqrt[4]{24024} = 12\frac{1}{2}$ approximately, if the required integers exist, they must be those distributed uniformly about $12\frac{1}{2}$, viz. 11, 12, 13, 14.

Also solved by W. W. Gorsline, Chicago, Ill.; Margaret Jean Sinclair, Waukegan, Ill.; A. J. Patterson, Wheeling, W. Va.; B. A. Johnson, Statesboro, Ga.; Leo A. Aroian, Fort Collins, Colo.; Charles W. Trigg, Los Angeles, Calif.; W. E. Buker, Leetsdale, Pa.; A. P. Kenyon, Chadwick, Ill.; E. S. Mulnix, Chicago, Ill.; Mack Tucker, Brennen, Ill.; Boris Garfinkel, Buffalo, N. Y.

Note: The Editor makes an effort not to let errors enter in the material given to the printer. When such errors do enter, he is glad to offer corrections. This explains the discussion which follows:

1197. *Proposed by Harry Frye, Tullahoma, Tenn.*

(See February, 1932, issue, page 213.)

Correction by Charles W. Trigg, Los Angeles, Calif.

The solution printed makes the incorrect assumption that O bisects HK and consequently that the semi-minor axis of the ellipse equals $\frac{LM}{2}$. Inspection quickly shows that the minor axis of the ellipse will intersect HK between O and K.

The correct value may be found as follows: The equation of the cone with the Z-axis as its axis and the origin as its vertex is,

$$X^2+Y^2=\frac{Z^2}{16}$$

Rotating the X and Z axes through 30° gives the equation of the cone to be

$$47X^2-34XZ\sqrt{3}+13Z^2+64Y^2=0$$

The intersection of this surface with the plane, $Z=3$, gives the ellipse,

$$47X^2-102X\sqrt{3}+64Y^2+117=0.$$

Transposing the origin to the point $\left(\frac{51\sqrt{3}}{47}, 0\right)$ gives

$$2209X^2+3008Y^2=2304$$

$$\frac{X^2}{\left(\frac{48}{47}\right)^2}+\frac{Y^2}{\left(\frac{6\sqrt{47}}{47}\right)^2}=1$$

Whence, the semi-major axis $=\frac{48}{47}$,

the semi-minor axis $=\frac{6\sqrt{47}}{47}$.

The corrected rainfall $=\left(\frac{48}{235}\right)^2\sqrt{\frac{47}{3}}=0.1651$ inches.

This is only correct if the entire rainfall is vertical, otherwise the effective opening will become larger or smaller dependent upon the angle of fall.

FOR HIGH SCHOOL STUDENTS

As suggested in the December issue, the Editor would like to enlist the interest of high school students in the easier problems proposed for solution. For those high schools whose classes in mathematics or mathematical clubs or students as individuals make noteworthy contribution to this department the Editor will give honorable mention. Teachers are urged to make report to the Editor of extensive study as suggested above.

HONORABLE MENTION

1210. *Woodston (Kansas) High School Trigonometry Class.*

1213, 1916. *Albert Whiteman, West Philadelphia High School.*

1216. *Chester Meyer, Rural High School, Woodston, Kan.; Vernon Godsey, Howard B. Dilatush, and Herman Maass from Lewis and Clark High School, Spokane, Wash.*

PROBLEMS FOR SOLUTION

1229. *Proposed by the Editor.*

In two triangles if a side and an angle of one are equal respectively to a side and an angle of the other, and if the angles opposite the equal sides are supplementary, then the sides opposite the equal angles are equal.

1230. *Proposed by D. A. Lehman, Goshen, Ind.*

If $a : b = c : d$, and a, b, c, d are positive and in order of magnitude, prove that $a+d > b+c$.

1231. *Proposed by F. H. Wade, Lewis Institute, Chicago.*

If BAD is an angle inscribed in a semicircle, with AD as diameter, find the value of $\angle A$ so that AB divides the area of the semicircle into two equal parts.

1232. *Proposed by Harry Frye, Tullahoma, Tenn.*

ADE is an equilateral triangle. BC is parallel to DE, with B on segment AD and C on segment AE. $BO = 15$, $OC = 10$, $OE + DC = 100$. Find the area of the triangle.

1233. *Proposed by J. L. Stearn, Washington, D. C.*

Construct a plane triangle having given the vertical angle, the bisector of the vertical angle and the difference of the two sides including the vertical angle.

1224. *Proposed by Israel Rubin, Brooklyn, N. Y.*

Give a method for finding pairs of consecutive numbers the sum of whose squares is itself a perfect square.

SCIENCE QUESTIONS

May, 1932.

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

Readers are invited to co-operate by proposing questions for discussion or problems for solution.

Examination papers, tests, and interesting scientific happenings are very much desired. Please enclose material in an envelope and mail to Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio. Thanks!

WHO IS THE ENGINEER?

595. A train is operated by three men, Smith, Robinson, and Jones. They are fireman, engineer, and brakeman, but not respectively. On the train are three business men of the same names. A Mr. Smith, a Mr. Robinson, and a Mr. Jones. Consider all the data about all concerned.

1. Mr. Robinson lives in Detroit.
2. The brakeman lives half way between Chicago and Detroit.
3. Mr. Jones earns exactly $2,000 a year.
4. Smith beat the fireman at billiards.
5. The brakeman's nearest neighbor is one of the passengers and earns exactly three times as much as the brakeman.
6. The passenger whose name is the same as the brakeman's lives in Chicago.

The Question Is—*Who is the Engineer?*

(The above question is reported to be used as a test in selecting employees. Come on, psychologists! Tell us just what it will tell about a candidate's qualifications.)

Solution by J. S. Georges, Chicago, Ill.

Here's my solution of the Test No. 595:

1. Robinson is not the brakeman. See 1 and 2.
2. Brakeman's nearest neighbor is not Mr. Jones. See 3 and 5.
3. Mr. Jones lives in Chicago. From (1) and (2).
4. Jones is the brakeman. See 6, and (3).
5. Smith is not the fireman. See 4.
6. Smith is the engineer. From (5) and (4).

Time, 6 minutes.

Solution by Herbert S. Lein, North Tonawanda, N. Y.

I am very much interested in your test No. 595 published in the February edition of SCHOOL SCIENCE AND MATHEMATICS. The answer came to me in about 15 minutes but I shall appreciate your verifying both the answer and the steps in the reasoning.

The brakeman's nearest neighbor must be Smith because Robinson lives in Detroit and Jones fits the case of the man living in Chicago because of his $2,000 salary (unreasonable to have a brakeman earn only $666). Therefore Jones is the brakeman.

Robinson is ruled out as the engineer right from the start since the problem states that the names are not in respective order. Consequently Smith must be the engineer.

Is this solution correct?

Solution by A. P. Kenyon, Chadwick, Ill.

I am answering your request in SCHOOL SCIENCE AND MATHEMATICS concerning problem No. 595 by stating that I worked slightly over 30 minutes before concluding that Smith is the engineer, Jones the brakeman, and Robinson the fireman. My solution is based on the location of the homes of the passengers. It is known that Mr. Robinson lives in Detroit. Mr. Jones can not be the brakeman's nearest neighbor because $2,000 is not an exact product of three and any number of dollars and cents; therefore Mr. Jones must live in Chicago and the brakeman's name is Jones. But Smith cannot be the fireman, so he must be the engineer and Robinson the fireman.

What do YOU think about it?

WHO IS THE ENGINEER?

(Please answer the following promptly.)

604. *Proposed by Carl G. Campbell, George Peabody College for Teachers, Nashville, Tenn.*

DOES CHLORINE BURN IN AN ATMOSPHERE OF HYDROGEN? Whether your answer is "Yes" or "No," give reason.

[This question has been causing some discussion during the past few months, so I am anxious to find out what your readers think about it. One suggestion has been that only the reducing agent (hydrogen in this case) may be said to burn, while the oxidizing agent (chlorine in this case) supports the combustion of the hydrogen. Other cases, similar to this, might be cited, but this illustrates the point at issue.—C. G. C.]

603. *Question*—What is the fastest mile ever traveled on land?

Answer—253.968 miles per hour, officially approved by the American Automotive Association, driven by Sir Malcolm Campbell, England's speed king at Daytona Beach, Fla., Feb. 24, 1932. "I am not at all pleased with the record," the 47-year old driver said, as he climbed out of his car to receive an ovation from thousands of spectators. (News Item.)

MORE TESTS IN PHYSICS

605. *Your Comments and Discussion are Desired.*

W. R. U.—CLEVELAND UNIT TESTS IN PHYSICS—LIQUIDS, TEST NO. 3, A

Problems

(Test constructed by David W. Evans, West High School, Cleveland, Ohio and David P. Harry Jr., Graduate School, Western Reserve University.)

Name ..... Date .....Score (.....)

Directions: Solve each problem and place the answer on the line at the right. Show your work on this page.

1. The water pressure at a depth of 20 cm. in water is _____
2. Find the pressure at a depth of 10 cm. in mercury (Sp. gr.=13.6) _____
3. Find the pressure in lbs. per sq. in at a depth of ten feet in water. (One decimal place.) _____
4. A brick lost 2 lbs. when submerged 1 ft. deep. How much would it lose if submerged 5 ft.? _____
5. A cubic foot of stone weighs 270 lbs. in air. How much would it apparently weigh in water? _____
6. Forty cu. cm. of a substance weighs 100 gms. in water. How much does it weigh in air? _____
7. A stick of wood, volume 1000 cu. cm. and sp. gr. .6 floats in water. How many cu. cm are above water? _____
8. A stone weighs 12 pounds in air and 8 lbs. in water. Find its specific gravity. _____
9. A cube of zinc weighs 210 g. out of water and 180 g. in water. What is its sp. gr.? _____
10. An empty bottle weighs 30 g. Full of water it weighs 100 g. and full of brine it weighs 114 g. Find sp. gr. of brine. _____
11. A stone weighs 60 g. in air, 30 g. in water and 34 g. in alcohol. What is the sp. gr. of this alcohol? _____
12. A piece of wood weighing 80 g. in air required an additional force of 40 g. to submerge it. What is the sp. gr. of the wood? _____
13. The large piston of an hydraulic press is 300 sq. in. in area; the small one is 6 sq. in. What force on the small piston is needed to lift 2000 lbs. on the large one? _____

EXAMINATION PAPERS

Please send copies of any recent examinations or tests to the *Editor*. Other teachers are interested.

SKUNKS IN TOWN DOUBLE WEIGHT

The prodigal skunk that deserts his country home and goes to live in town increases his substance by riotous living.

Prof. W. J. Hamilton, Jr., of Cornell University, has examined nearly five hundred specimens of skunks, and finds that those caught in towns weigh ten or twelve pounds, as against five or six pounds for their countrybred brethren. The town skunks' stomachs showed that they were devotees of the easy living offered by garbage piles; they contained breadcrusts, meat, eggshells, fruits and even coffee grounds.

In the wild, a skunk's diet consists mainly of insects, so that he is a useful ally of the farmer. Countrybred skunks examined by Prof. Hamilton often had their stomachs distended with grasshoppers. Other harmful insects that are favorite skunk tidbits are white grubs and cutworms.—Science Service.

BOOK REVIEWS

Field and Camp Notebook by Comstock and Vinal. A loose-leaf notebook for nature study assembled in a leatherette cover. 150 sheets. 9½x17 cm. The Slingerland-Comstock Company, Ithaca, New York. Price $1.25.

This notebook is designed for both teachers and students. It is assembled from a wide variety of 600 different forms; teachers may select from the catalog such sheets as are best adopted to their nature study courses. Subjects treated are Birds, Trees, Flowers, Ferns, Insects, Fish, and Nature Games; many other topics can be selected from the catalog. Excellent outlines, charts, and drawings go with each unit. A flower key and check list of 209 wild flowers is available; a chart of insects by the month is also provided. Many hints on the best way to carry on nature study may be found in these sheets. As assembled these sheets present a course such as has been found most useful in the training schools for teachers. The material it contains should find a place, in part or whole, in Biology and General Sciences classes; nature study clubs should also find them valuable. For systematic nature study to supplement classroom science courses these outlines are unexcelled. W. F. Roecker.

A Course of Quantitative Analysis by J. Samuel Guy, Professor of Chemistry, Emory University, and Augusta Skeen, Assistant Professor of Chemistry, Agnes Scott College. 1st edition. xiv+242 pages. 1.5x15x21 cm. Illustrated with a number of figures. Cloth. 1932. $2.20. Ginn & Co.

This new text seems to the reviewer to be most teachable. Fifteen pages of a brief review of some chemical theories are followed by 23 pages of General Directions which are very clearly put. Part I then takes up Volumetric Analysis which the authors believe more suitable for beginners than gravimetric work. "Volumetric procedures" they say, "yield more progress with a given amount of work, they are less exacting in their demands on the student, they are less open to serious error, and, all in all, better adapted to a beginner in the subject." Eleven approximately decinormal solutions are prepared, giving the student a chance to grasp the conception of normal solutions of acids, bases, oxidizing and reducing solutions and precipitating agents. These solutions are used to get milliliter relations of each to the others. Then a number of the solutions are standardized against weighed quantities of chemically pure substances, and the normality of the others calculated from the milliliter relations. Analysis of unknowns follows. Then simple gravimetric work is taken up. The first section covers representative types of simple gravimetric procedures, the next section gives optional experiments in analysis of such things as a nickel coin, a natural phosphate, a limestone, etc. The remainder of the text is devoted to a study of hydrogen ion concentration, the first part being a discussion of the theory involved and the rest, determinations of the pH values of various solutions, with or without buffers, by colorimetric methods. The explanations are excellent and might well be studied by many workers who make their living by making pH determinations. They might get a realizing sense of what they were doing! As an elementary text of qualitative analysis this book would appear to be most usable. F. B. Wade.

Perkin and Kipping's ORGANIC CHEMISTRY, an entirely new edition, by F. Stanley Kipping, Ph.D , Sc.D., F. R. S., Professor of Chemistry, University College, Nottingham, and F. Barry Kipping, M. A., Ph.D., University Demonstrator in Chemistry, Trinity College, Cambridge Pages xi+614+xix. 3x14x19 cm. Illustrated with 24 cuts of apparatus. Cloth. 1932. Lippincott.

An entirely new edition of an old and well known text. Those who

are familiar with the sterling qualities of the previous editions will welcome this recent edition. By the use of two types of print, the authors have indicated both a brief and a longer course, so that different types of students may be suited. The order of treatment has been considerably changed especially in Part I. These changes have made it easier to correlate the laboratory work and the lecture work. Summaries have been added to many of the chapters to aid the student in getting the fundamentals well in hand. An excellent brief treatment of the organic dyes has been added. F. B. Wade.

Mastery Units in Physics by Clifford Holley, Instructor in Physics, University of Chicago High School, and Vergil C. Lohr, Instructor in Physics, University of Chicago, also Instructor in Physics at Central Y. M. C. A. College, Chicago. Cloth. Pages xvii+700. 13.5x19.5 cm. 1932. J. B. Lippincott Company, 1249-1257 S. Wabash Avenue, Chicago, Illinois. Price $1.88.

In recent years much of the activity in education has been centered in the organization of subject matter into comprehensive units of study. Physics courses in many school systems have been operating on this plan by mimeographed or printed outlines, but up to this time no textbook so organized was available. This book comes from the home of Unit organization and the "mastery" aim. The authors have by experimentation selected a series of units, each having a central idea essential to the comprehension of physical phenomena. They have attempted to develop a technique of presentation which will insure a complete understanding of each unit. The plan of organization for each unit consists of (1) an overview of the unit which gives the pupil the central theme and shows the relation of secondary ideas to it; (2) assimilative material consisting of discussions, laboratory exercises, questions, and numerical problems; (3) suggested topics for recitation and for further investigation.

An examination of the assimilative material reveals no radical changes in either the selection of subject matter or in the method of treatment. Neither the table of contents nor the unit tables point out specifically the traditional divisions of the subject but the conventional plan is followed: four units in mechanics, one of heat, one of sound, one of light, two of electricity and one on radiant energy. The selection of language is exceptionally well suited to give the student an understanding of the subject matter and the illustrations are excellent. But, except for the "overview" and the laboratory exercises being included at the proper place in the text book, there is little to insure that the plan of study recommended by the authors will be carried out. There is nothing definite to assist the teacher trained in the traditional methods of presentation to carry out the mastery unit plan. As a combined textbook and laboratory manual the text will no doubt appeal to many. It is an excellent text and merits serious consideration when adoptions are being made. But it is not much more likely to accomplish the aim of the authors than any one of a number of other good texts. The real presentation is still in the hands of the teacher. The reviewer is acquainted with the excellent teaching the authors are doing and wishes to congratulate them and the publishers on the excellency of the book. But would not the time spent on the production of the text have yielded a greater contribution to teaching, if they had devoted it to the production of a series of definite outlines of these units, suggesting many activities to aid in mastery of the fundamental ideas and giving definite references to the assimilative material in several texts? Such a study manual is needed in this field, both for guidance of pupils and for teachers who have had no special training in the organization of units and who have teaching loads so heavy that there is no time for such activity. G. W. W.

Seed Dispersal, a Student-Made Book edited by William A. Matheny, Professor of Civic Biology and Botany, Ohio University. Cloth 141 pages. 13x19 cm. 1931. The Slingerland Comstock Company, Ithaca, New York. Price $1.50.

This is an unusual book and a pleasure to the reviewer. Being student-made it is original in its treatment of the material. The figures are also student-made. Much of the discussion is based on actual observations and experiments by the students.

The text begins with "Bird Distributors" of seeds, and the following are *some* of the topics discussed in the first chapter. Birds as travelers and carriers of seeds, seeds carried in dry earth or mud, seeds that adhere to birds with experiments to show how great is the adherence of seeds to feathers, mucilage covered seeds, seeds transported in nest material, seeds distributed from the beaks of birds, seeds that pass uninjured through the birds digestive system, regurgitated seeds, dead birds as seed distributors, etc. The above list of topics will give you a better idea of the scope of the book than any description the reviewer can offer.

As aids for study there are reference lists at the ends of chapters and suggestions for study, experiment and research. It is a provocative book and capable of being very useful in school work.

W. Whitney.

Forest Facts for Schools by Charles Lathrop Pack and Tom Gill. Cloth. 12x18 cm. 136 pages with 33 figures in the text. 1931. Published by the Macmillan Company, New York. Price $1.00.

The authors are very much interested in their subject and have written this book to interest our young people in the subject of forestry by putting before them the important facts of forestry in really readable form, but yet not failing in the scientific presentation. The book is wholly original in its treatment of the material including the illustrations which are all carefully designed for aiding in putting over the facts being presented.

The text is introduced by a soliloquy entitled, "The Sequoia Speaks." Then follow chapters on getting acquainted with trees, how trees grow and multiply, how forests help mankind, forests of long ago, forests of the world, forestry in the National forests, forestry and wild life, forest products, forest enemies and in conclusion "The Task Ahead." The above is not a complete list of topics but is designed to show the mode of treatment of the subject.

The teaching point of view is not neglected. At the end of each section and unit are list of questions and problems for the student ingeniously designed to assist the pupil in reviewing the preceding pages, with also summaries interspersed for further review.

We cannot say enough in praise of this book. It is interesting, readable and scientific. Teachers of botany and general science should get acquainted with it. They will be repaid. W. Whitney.

Alte Und Neue Mathematische Spiele by Dr. Gerhard Kowalewski, O. O Professor Der Reinen Mathematik an Der Technischen Hochschule Zu Dresden. Cloth. Pages vi+145. 13x20.5 cm. 1930. Verlag Und Druck Von B. G. Teuber, Leipzig. 10 00 m.

This little volume by Prof. G. Kowalewski treats of five different mathematical games or groups of games: (1) the colored cubes of Major MacMahon, (2) the Mysterious Screen or Mind-reading Screen (W. W. Ball in his Mathematical Recreations calls it the "Window Reader"), (3) the Nim or Fan Tan or Three Pile game, (4) Rearrangement games (Anordnungsspiele), (under this heading are treated the Boss Puzzle in a variety of forms, the famous "schoolgirl problem," and the so-called unicursal problems such as Euler's problem, Hamilton's dodecaeder problem, etc.), (5) Solitaire games (not for cards, however, but to be played with pieces on specially formed checker boards).

As indicated in the title, most of these games are not new; new, indeed, are only certain variants of the games described here. Nevertheless the presentation is unique enough to deserve fullest interest. Writing for readers with little more than elementary knowledge of mathematics the author succeeds admirably in conveying, not merely an understanding of the performance of the games, but a fairly complete insight into the nature of the mathematical problems involved and of the reasoning leading to the one or several solutions. Beginning each time with a short description of the game as such the author next strips it of all accidental elements thus laying open the mathematical essence of the problem. This he next proceeds to develop thoroughly and completely, carefully defining all terms and concepts, though always in non-technical language. Beginning with simple special cases which aim to bring out the principle of reasoning unobscured by cumbersome complexities he afterwards again broadens the inquiry to the desired generality. In the end he returns to the various forms of the game in question frequently with suggestions for possible modifications, suggestions referring in particular to improvements of the concrete forms in which the game is played aiming at more puzzling or more amusing or altogether more impressive ways of embodying the idea of the game. The author indeed repeatedly expresses his desire to stimulate the production of new and cleverer sets for these games by amateurs or toy manufacturers.

The style of the book is very agreeable: short, clear sentences—none of those breathtaking structures which often make the reading of German texts a somewhat laborious task. It is printed in Latin script. A wealth of illustrative, carefully denoted figures accompanies the text throughout. The little volume should be of great interest and value especially to people, teachers or students, active in Mathematics clubs in High School or college. Louise Lange.

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Corwin Science Series, Book I, The Science of Human Living, pages 450, price $1.68; *Book II, The Science of Plant and Animal Life,* pages 650, price $1.72; *Book III, The Science of Discovery and Invention,* pages 750, price $1.80, *by Walling Corwin, San Diego Senior High School and Mae Johnson Corwin, Phineas Banning High School, Los Angeles.* Harr Wagner Publishing Co., San Francisco.

This science series is intended for use in the Junior High School. The "Science of Human Living" is the first book and is written for use in the seventh grade. It is a practical health book, emphasizing personal and community hygiene. Only slight consideration is given to structural physiology. The book is divided into the four principal units—Foods and Health, Personal Health, General Health, and Health in the Home. Each unit is further subdivided into projects. Each project contains a brief introduction, questions to be answered, descriptive and informational material and things to do. The book is well constructed mechanically. The type is large and clear. The book is fairly well illustrated. The usual teaching helps are missing.

"The Science of Plant and Animal Life" is the second book in the series and is written for the eighth grade. It includes a study of plants and animals exclusive of the human body. This book is divided into the principal units—Introduction and the Study of the Simple Cell, Seed-bearing Plants, Spore Bearing Plants, The Animal Kingdom, and Agronomy. Each unit is again subdivided into projects. Each project, in addition to those mentioned in Book I, contains a specific set of references. In some projects additional experiments are suggested. The subject matter has been selected to give the pupil a thorough understanding of and appreciation for living things.

"The Science of Discovery and Invention" is intended for use in the ninth grade. The subject matter is based on chemistry, physics, astronomy and geology. Biological science has been omitted. The principal units are—Glimpses Into Chemistry, Glimpses Into Astronomy, Units of Measure, Machines and Work, Heat, Electricity, Sound, Light, Air, Water, Materials and Construction, Energy, Force and Motion, and Changes on the Earth. The Units, as before, are divided into projects. Several experiments are included. The unit on chemistry includes much more material than is ordinarily included in ninth grade science. Results of investigations seem to show that much of this material is too difficult for pupils of this age. Some of the better pupils may be able to understand it.

This series offers a three-year course in general science. Duplication of material is eliminated. The authors claim that all of the material has been tested in the classroom. The results do not agree with some of the results of other investigators. This series merits the careful attention of all teachers of science in the Junior High School. I. C. D.

Children of a Star by Julie Closson Kenly and illustrated by Henry C. Kenly. Cloth. Pages x+241. 13x20.5 cm. 1932. D. Appleton and Company, 35 West 32nd Street, New York. Price $2.50.

Children of a Star is a story of the development of life on the Earth. Starting with the "magic jelly" of the amoebas the narration proceeds with hydras, corals, clams, and sponges, gives vivid pictures of many forms of sea life, and tells how the story of progress is preserved in fossil records. Crayfish, spiders, insects are interesting creatures as described here with now and then a myth or fairy story to aid the description. A chapter on "dangerous ladies," the mosquitoes, another on bees, one on butterflies, and so on with birds, fish, pre-historic reptiles, "furry folk," and finally, man. The book is a storehouse of nature lore and will stimulate interest in elementary science. G. W. W.

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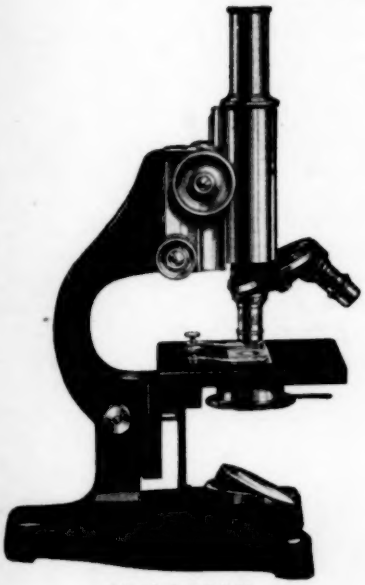

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Recent Advances in Physics (Non-Atomic), by F. H. Newman, University College, Exeter, England. Pages 378+ix, figs. 51, 13x20 cm. Cloth. P. Blakiston's Son & Co., Philadelphia, 1932. Price $4.00.

This is one of the few surveys of recent advances in theoretical and experimental physics that gives attention to so-called non-atomic phenomena, such as acoustics, high pressure effects, the viscosity of liquids, low temperatures, and high vacuum technique. Atomic physics receives its share of attention, however, in such topics as the wave-like character of matter, statistical mechanics, and magnetism. The treatment of magnetism is relatively quite comprehensive, occupying as it does about one-fourth of the book.

The treatment is not intended to be popular in nature. It should prove to be profitable reading for the earnest advanced student or college teacher who desires a summary, or review, that is sound in character. Since, as Professor Newman points out, there are published annually some 4000 papers embodying results of original work in physics, it is not surprising that most of us must obtain much of our knowledge of recent developments in physics from second-hand sources. As Voltaire once said, "The multiplicity of facts and writings is become so great that everything must now be reduced to extracts."

Duane Roller.

Lives in the Making by Henry Neumann, Ph.D., Leader, The Brooklyn Society for Ethical Culture. Pages ix+370. 1932. D. Appleton & Company, New York.

This book is an interesting illustration of the attempt, less successfully made by others, to reconcile scientific findings with ethical ambitions. The thesis of the book is summed up in its three major divisions: 1. What Home and Community Can Do; 2. Where Psychology Can Help; 3. What Schools Can Do.

In the first division Neumann treats of the social relations in the home, the factory, the church, and the community. In the second division he deals with mental hygiene, intelligence and individual differences, and finally the problems of personality. In the third division the author discusses the task of the teacher and the development of a social outlook in the field of education. Learning by doing, literature and art, the social studies, the natural sciences, and mathematics are some of the topics treated. There is a conclusion in which the chief trends of the discussion are reviewed under a few major concepts.

The book represents a mature philosophy of life, a thorough appreciation of what is and what is not acceptable in present-day scholarship in the social sciences, and an ability to transmit to others what the author himself appears to practice and believe. There are many hints of value to the teacher who has not yet found himself and to the floundering parent who "follows the line of least resistance." Let him who is thirsty come and drink.

Maurice H. Krout.

Kostychev's Chemical Plant Physiology written and revised by Dr. S. Kostychev, Member of the Russian Academy of Science, Professor in the University of Leningrad and translated and edited by Charles J. Lyon, Assistant Professor of Botany at Dartmouth College. Portrait and 45 illustrations. Cloth. Pages xv+497. 15x23 cm. 1931. P. Blakiston's Son and Company, Inc., 1012 Walnut Street, Philadelphia, Pa. Price $6.00.

This is a very important text recently appearing in German and now translated by Professor Chas. J. Lyon of Dartmouth College. It is a part of a German text, The Lehrbuch der Pflanzen Physiologie which appeared in 1926 and was revised between 1926 and 1929 to incorporate important advances in the knowledge of chemical

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"This volume deals with chemical physiology. First there is an exposition of the assimilation of the elements required by plants. Then follows a description of the transformations of the assimilated foods in connection with the various vital requirements of plants. Finally there is a discussion of the biochemical processes which furnish energy to plants." As will be surmised this is a book for the advanced student of botany and chemistry and presupposes a knowledge of the fundamental principles of organic chemistry. It is a valuable book for teachers and students thus equipped to make use of it.

W. Whitney.

A COLLEGE COURSE IN RADIO

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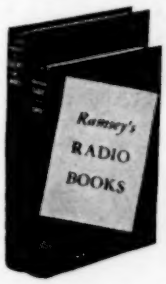

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BOOKS RECEIVED

How to Understand Chemistry by A. Frederick Collins. Illustrated. Cloth. Pages xii+321. 12x18.5 cm. 1932. D. Appleton and Company, 35 West 32nd Street, New York. Price $2.00.

A Course in Quantitative Analysis by J. Samuel Guy, Professor of Chemistry, Emory University and Augusta Skeen, Assistant Professor of Chemistry, Agnes Scott College. Cloth. Pages xiv+342. 14x20.5 cm. 1932. Ginn and Company, Number 15 Ashburton Place, Boston, Mass. Price $2.20.

First Year Algebra by David A. Rothrock, Professor of Mathematics, Indiana University and Martha Anne Whitacre, Head of Mathematics Department in the Junior Senior High Schools, Richmond, Indiana. Cloth. Pages xi+320. 12.5x19 cm. 1932. Charles Scribner's Sons, 597 Fifth Avenue, New York. Price $1.20.

The Skycraft Book by Laura B. Harney, Teacher of Science, Washington Junior High School, Mount Vernon, New York, and Licensed Airplane Pilot. Cloth. Pages xi+338. 12 5x19 cm. 1932. D. C. Heath and Company, 285 Columbus Avenue, Boston, Mass. Price $1.08.

Teaching the Primary Grades by Dorothy Bildersee, Principal in the New York City Public Schools. Cloth. Pages xix+332. 13.5x19 cm. 1932. D. Appleton and Company, 35 West 32nd Street, New York, N. Y. Price $2.00.

Problems and Questions on Chemistry by Franklin T. Jones. Fourth Edition. Paper. Pages viii+66. 13x19 cm. 1932. The University Supply and Book Company, 10109 Wilbur Avenue, S. E., Cleveland, Ohio. Price 50 cents.

Instructional Tests in General Science for Junior and Senior High Schools by Earl Glenn, Head of High School and College Science Departments, New Jersey State Teachers College at Montclair and Benjamin C. Gruenberg, Formerly Head of Science Department, Julia Richman High School, New York City. Illustrated. Paper. Pages iv+92. 16x25 cm. 1932. Price 36 cents. A separate Key for answers to the tests, price 16 cents and Teachers Manual, price 16 cents. World Book Company, Yonkers-on-Hudson, New York.

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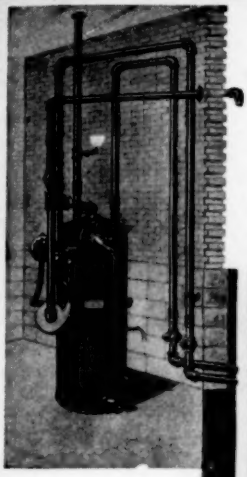
A joint committee of our two national entomological societies has made the Fifth International Congress of Entomology at Paris the occasion for arranging two cooperative European trips presenting very attractive features at unusually low expense. Although



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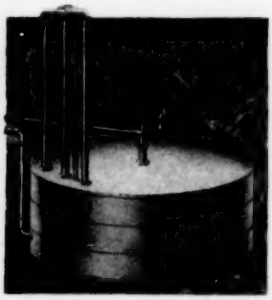

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primarily for entomologists the trips are open to other compatible persons. As the program at stopping places will not be set, but will be optional with the individual, those who wish to devote their time to sight-seeing or to any particular activity will have ample opportunity to do so.

Group A sails from New York June 7th on the SS. Leviathan, visiting Bremen, Hamburg, Rostock, Copenhagen (3 days), Lund, Stockholm (4 days), Upsala, and Lapland, Land of the Midnight Sun. The trip to Stockholm will include some hours on the Gotha Canal, on Midsummer Eve, when all the village folk in Sweden dance all night around the May-poles. The journey to Lapland will be over a railway that is said to pass through the most magnificent scenery to be seen from any railroad in the world, with a single exception. There will be time for an optional four-day excursion by steamship from Narvik on the Norwegian coast to the North Cape and back ($20.00 additional expense). Returning through Germany to Holland, the group will visit Amsterdam (2 days), Brussels, Bruges, Middelburg (on market day), Paris (9 days), the Cro-Magon caves at Les Eyzies, the high Pyrenees, Carcassone and Avignon, the high Alps near Chamonix (3½ days), Genoa (2 days), Naples (4 days), Rome (3 days), Assissi, Perugia, Florence (3 days), Bologna, and Venice (2 days). Then they will cross over the Brenner Pass to the Eibsee in the Wetterstein Alps (2 days), visit Munich, the three finest of the walled medieval cities (Dinkelsbuhl, Rothenburg, and Nuremberg), Leipzig (during the autumn fair), Dresden, the Spreewald, Berlin (4 days) and end with a week in London, sailing for New York on the SS. Lapland, September 17. The estimated expenses (including an allowance for side-trips and personal extras) are $800.

Tour B, sailing from New York on the Olympic, July 1, will return on the Manhattan, sailing August 26. They will cover approximately the same ground with the exclusion of Scandinavia and Italy. The cost is estimated at $550.00. Combinations of the tours can be arranged, or parts taken.

A pamphlet giving details of the trips may be secured on application to the Chairman of the Committee, Professor O. A. Johannsen, Roberts Hall, Cornell University, Ithaca, N. Y.

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